UNIVERSITY OF LIVERPOOL

USER CENTERED PASSIVE BUILDING DESIGN

IN THE NAME OF GOD. THE MOST BENEFICENT, THE MOST MERCIFUL

USER CENTERED PASSIVE BUILDING DESIGN

Thesis submitted in accordance with the requirements of the University of Liverpool for achieving the degree of Doctor in Philosophy

By

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ABSTRACT

The full integration of End User Factors (EUFs) into the building design processes environment is still emergent. It has been suggested from other sectors that the integration of EUFs into design can improve work performance and promote the workforce's physical and mental health. The need for EUFs in the passive design strategies (PDS) (i.e., ventilation, day lighting and thermal comfort) has become a prerequisite condition from clients to enhance the user experience and harmonise their activities with PD performances. MFE (2011) claimed that architects are not fully engaged in the integration of EUFs in design. "The design team should involve future users and facilities management staff in the design process, and develop a building user's guide to inform occupants of the building's design intent". This research has carried out an intensive literature review into user centred design (UCD) methods and factors in the building, engineering and IT industries. The investigation spans from 1955 to date. The literature showed that there are no coherent models in the building industry that capture the total EUFs as portrayed in ISO standards. However, in the IT industry the theory of UCD is well advanced and developed.

The methodology that is followed by this research is based on a critical analysis of the literature and prototype modelling. To ensure the appropriate EUFs are selected and integrated into design, the author needs to investigate what are the most relevant EUFs and how to integrate them into various PDs. To carry out this process effectively the author developed a systematic process that captures EUFs in the design processes. First, the research investigated PDs and clustered them under three dimensions, which are passive ventilation, passive lighting and passive heating (PLVT). Second, the investigation sought to understand the difference between users (Us) and end-users (EUs). This has resulted in creating classes of Us and EUs so that the extracted factors are mapped into these classes. Third, the research used ISO 13407 and ISO 9126 standards to develop a conceptual model. The first standard is used to organise the processes of UCD into coherent and dynamic steps. The second is used to systemise PD attributes (ATTs) and sub-attributes (S-ATTs) and map them into the processes that are developed in the previous stage, that is to say, according to ISO 13407. The output from this is the creation of a conceptual user centred passive building design model "UCPBD". The model aims to assist designers to assess their design for the inclusion of EUFs. The model could be used for both PDs and non PDs.

The research has considered 132 EUFs. A questionnaire was used to identify the most influential factors. The questionnaire was distributed among architects' professionals. The results were analysed using several statistical methods. The analysis shows a disparity of the ranking of the degree of influence and usage among the surveyed groups. The most effective

factors were 44 out of 132 EUFs. There was a statistical difference at the $p<0.05$ level significant for four factors out of 132 factors. These are BB1: Durable, high quality finishes, BG2: Utility PD cores uniformly designed and vertically stacked, DA8: Design passive space that responds to changes in spatial dimensions (volume) and EB2: Use high quality material with long service life to handle passive functions in terms of professional role. In terms of the architect experience only nine EUFs out of 132 EUFs were rejected. These are AA2: Orient the building for optimum lighting, ventilation and thermal comfort, AC11: Narrow floor width to optimise natural ventilation, AC12: Provide solar-oriented interior zone to store and maximise solar heat gain, AE9: Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort, BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast), CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas), DA10: Design passive layout based on future use scenarios, EB3: Consider the rate of expansion/contraction of material of PDs and FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features. The post hoc comparisons using the Tukey HSD test also indicated these differences between four EUFs in terms of professional role and nine EUFs in terms of experience but found no significant differences between 128 and 123 EUFs respectively. The results of the cluster analysis indicate that the most influential EUFs can be grouped into six clusters. These are: passive design functionality (PDF), passive design performance (PDP), passive design usability (PDU), passive design flexibility (PDFL), passive design reliability (PDR), and passive design maintainability (PDM). The clusters are grouped according to ISO standards. The result validity testing shows that selected clusters are characterised by strong relationships. Only the reliability of PDR cluster shows low conformity (.539, but it is still acceptable statistical limits. The clusters are used to develop an assessment tool to map EUFs into PD processes. The model is generic and can be used as a tool to evaluate PDS for the inclusion of EUFs. The model was validated on four projects, which are namely Houghton Street Project, Cherry Mill Project, Fitzroy Street Project and Tullis Russell Environmental Education (TREE) Centre, to demonstrate the use and capabilities of the proposed model. The results show Satisfactory, Significant, Significant and Highly Significant respectively.

This study is a first attempt to organise EUFs by using conceptual models, statistical as well as decision support tools. Accordingly, this leads to extend the theory of PD by systemising and incorporating EUFs. Overall, this investigation builds knowledge by extending UCD theory to the PBD context and by proving a list of effective EU factors. The results from this research can demonstrate and advance our knowledge in the area of PBD by integrating EUFs into the design process in a systematic way. Then, this will certainly lead to the design of highly-performing and resilient buildings. A design paradigm will help architects to rethink the integration of EU needs during the design process and create a cultural shift in design practices. By using EU needs as a benchmark for design assessment, the potential for improving the indoor environment and EU well-being in buildings is enormous. Also, the implication of this work is that it may lead to the design of high performing buildings and increase the satisfaction of the Us and EUs.

DECLARATION

I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged.

Signed………………………………………

Date………………………………………..

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List of Abbreviations

The Abbreviation	Meaning
ATT	Attribute
EU	End User
EUF	End User Factor
PB	Passive Building
PBD	Passive Building Design
PD	Passive Design
PDFL	Passive Design Flexibility
PDF	Passive Design Functionality
PDHA	Passive Design Human Attribute
PDM	Passive Design Maintainability
PDP	Passive Design Performance
PDR	Passive Design Reliability
PDS	Passive Design Strategies
PDU	Passive Design Usability
PH	Passive Heating (Thermal Comfort)
PL	Passive Lighting (Day Lighting')
PLVT	Passive Lighting,Ventilation and Thermal Comfort
PV	Passive Ventilation (Natural Ventilation)
S-ATT	Sub-Attribute
U	User
UCD	User Centred Design
UCPBD	User Centred Passive Building Design

Chapter One: Introduction

1.1 Introduction:

The design of buildings is a complex process and its complexity can be increased when the design strategy is based on passive design (PD). PD has been developed at the international level during the last decades. It is apparent in European countries, where it is one of the sustainable methods which rely on natural conditions such as passive lighting (day lighting) (PL), passive ventilation (natural ventilation) (PV) and thermal comfort (heating) (PH) (grouped together as PLVT), which of course leads to the laying off or reduced reliance on mechanical means. There are several definitions for PD; one of them is that *"A Passive House is a building, for which thermal comfort (ISO 7730) can be achived solely by postheating or postcooling of the fresh air mass, which is required to fullfill sufficient indoor air quality conditions (DIN 1946) - without a need for recirculated air"* (Feist, 2006). It is well documented how the environmental or ecological features direct the design process of PD. The end user factors (EUFs) were not placed as a main driver even though this definition gave an indicator about the indoor quality which, in one way or another, focuses on considering the end user (EU) requirnments. Even though EUFs are not used as the pivot around which the design carried out. For this reason, the architect should pay attention to consider the EU when specifying passive design strategies (PDS).

1.2 Rationale of this Study and the Problem Statement

Design is a process that involves several aspects; for this reason there are several definitions looking at design from different perspectives. Thorpe (2007, p.13) defined sustainable design as *"theories and practices for design that cultivate ecological, economic and cultural conditions that will support human well-being indefinitely"*. Craven (2011) defined green design as *"an approach to building that minimises harmful effects on human health and the environment"*. In these definitions, the occupant is one of the main issues that should be considered besides the environment issues when designing the building. For this reason, the designer should realise and understand the EU in each stage of design for each Attribute (ATT). The theory which deals with the EU as a centre of design components and ATTs is User Centered Design (UCD), which will be given an overview in the following paragraph.

The trend to concentrate on the EU needs through the design process has been highlighted in several studies and pieces of research. This was clear in computer and technology science. It is not limited to that; it is adapted from ISO standards such as 13407 and 9126 which end with the framework that can be used as guidance for designers to ensure that they are integrating the EUFs (Abram et al, 2003; EMMUS, 1999; ISO 13407, 1999; Earthy et al, 2001; and Bevan and Azuma, 1997). In fact these studies and standards covered several EUFs as part of design ATTs that have an influence on meeting EU needs. However, this is in terms of designing computers and technology. In terms of designing buildings, many authors have referred to the importance of fulfilling EU needs as follows. The need to incorporate EUFs into building design is highlighted by several authors. For example, The Ministry for the Environment (MFE) (New Zealand): Manatū Mō Te Taiao (2008, p.3) stated *"The design team should involve future users and facilities management staff in the design process, and develop a building user's guide to inform occupants of the building's design intent"*. Noticeably this statement advocates the integration of EUs' needs by the designer into the design requirements and specifications. The idea here is that the designer ought to meet EU needs before completion of the design. This is necessary because retrofitting the design post-construction to meet EU needs will be an expensive business. Ismail and Hokoe (2009, p.3) support the MFE statement by declaring *"The area that is still not covered is the research on human factors, especially the post-occupancy evaluation and the reuse or recycling of building products"*. The authors indicate the importance of research on EUFs and in particular issues related to post-occupancy evaluation. This study argues that post-occupancy factors must be incorporated into usability, durability and performance agenda at the design stage. EUFs should be considered during the development of the conceptual model and definitely before delivering the product to the EU. Karwowski (2007b, p.25) argued that *"The greatest challenge for HF/E today is to develop a new mission of sustainable human-centered"*. Karwowski's statement emphasizes the EUFs and ergonomics as an important issue that needs to be considered and developed over time. This statement stresses that the comfort of the EU is one of the main pillars of design. The Technology Strategy Board (TSB) (2009, p.4) has recognized the importance of UCD in all aspects of building procurement processes. It put forward the declaration that *"More expertise in human factors research and user-centered design is needed in engineering consultancies, product manufacturers, building designers, facilities management companies and others"*. As the TSB referred to the role of the designer in integration of the EU within the design, other authors such as Levin (2003) have also referred to this interaction. Levin (2003, p.26) said that *"Ultimately, provision of indoor environmental quality that will achieve the highest level of occupant satisfaction and the lowest impact on the environment must radically increase the use of so-called "passive" and "user-controlled" technologies, many of which are widely used in historically important examples. By integrating the analysis of the interactions between building, occupants, and the larger environment, researchers and designers will model successfully the fundamental relationships that should drive our design"*. This statement referred to the PDS such as PD that can lead to enhance the EU satisfaction. It also paid attention to the significance of delivering designs that meet EU and ecological needs. The mismatch between EU and designer can lead to an increase in EU complaints. This was highlighted and indicated by Goins and Moezzi, (2012, p.1), who claimed that *"When there is a mismatch between assumed and actual user needs or assumed and actual operators' practices, complaints can arise. These complaints might be viewed as part of the information gap between the incorrect or incomplete assumptions made during design and actual end-users needs and requirements"*.

These statements have identified the importance of EUFs and to what extent they should be part of the design process; they emphasize the necessity of considering the EU needs, as well as the importance of EUFs' effectiveness on the design. Meeting the EU needs is required to be considered at all ATTs of building design, on the one hand. On the other hand, there is a demand to think of systemic processes that enable EU needs to interact with PDS.

This research aims to bridge the gap between the EU needs and PDS through determining EUFs which could influence the use of passive building design (PBD). Various theories have considered the EUFs or referred to them; however, the various ATTs of EU issues have not been considered from the early stage. Some of them are looked at after the EU is using the building and others touch on some specific issues.

This study has conducted an extensive literature review to examine the previous theories of architectural design and to investigate UCD and EUFs. The extensive review of litrature has confirmed that the EU and UCD theories as described in ISO standards is not invistigated in the domain of building design.

The problem set for this study was to identify the EUFs which can have a clear impact on PBD. In addition to that, it was also important to think of the way in which EUFs can be integrated into the design process to enhance the architects' role to meet EU needs.

1.3 Research Questions

In order to achieve the problem statement, the study attempted to answer the following research questions:

- What are PBD strategies and how they will relate to the EU needs?
- What are the suitable methods for modelling, capturing and integrating EUFs into PBD?
- What are the most effective EUFs for UCPBD?
- What is the most appreciate tool for integrating EU needs into PBD design?

1.4 Research Hypotheses

The main hypothesis which drives this research is investigation of whether or not the architects consider EU needs when they carry out PBD. The motivation is to contribute to PD by determination the EUFs which can be considered by the experienced architects. The ATTs of the proposed model are utilized in the research questionnaire. That will explore if the architects relate the EU needs to PD. This is achieved through breaking the main hypothesis of this study into four hypotheses as follows:

A_x: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs on PBD.

A_{0x}: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs on PBD.

B_x: There is no obvious difference between the architects' perceptions regarding the consideration of EU aspirations in PBD.

B_{0x}: There is an obvious difference between the architects' perceptions regarding the consideration of EU aspirations in PBD.

1.5 Aim and objectives of this study

1.5.1 The aim of the Research

The main aim of this research is to investigate the EUFs in PBD and architects' understanding of the importance of considering EUFs when they are designing PBD.

1.5.2 The Objectives

- To review the architectural design theories, PDS and User definitions.
- To determine the suitable methods for modelling, capturing and integrating EUFs into PBD
- To identify the most effective EUFs for UCPBD based on a questionnaire and statistics analysis.
- To analysis, extract the most influential EUFs, discuss the result and propose an assessment tool that helps the designer to assess the level of meeting EU needs of PBD

1.6 Scope of the study

PBD as a trend is focused on ecological issues: how to benefit from the natural environment, which has been categorised as heating, ventilation, cooling and day lighting.

The scope of this study of the architects who practice PD is to ascertain if they consider EU needs in it. For this reason, a UCPBD model has been suggested to confirm whether or not the designers are considering and meeting EU meeds. To achieve this aim three steps have been considered.

The first step was through grouping the PDS lighting, ventilation and heating (PLVT) under five main areas (site, orientation and landscape, building form, space planning, roofs and façades), which is classified as one of the main ATTs of the model, namely PDF.

The second step was the development of a design process that the designer should follow to ensure that all ATTs of UCPBD are validated systamically.

The third step was identifying the ATTs (functionality, performance, usability, flexibility, reliability and maintainability). These ATTs were used to ensure if the EUFs were integrated or not, because one of the objectives of this study was to bridge the gap between the EUFs and PDS.

These ATTs were identified through searching for a method that considers EUFs during the design process. This led to reviewing and investigating a theory which can help the researcher to achieve this aim. After studying and analysing UCD theory, it seemed that theory will be effective in incorporating EU into PDS. Asystamatic review of litrature since 1954 to date show that UCD is not considered in any formal ways as in ISO standards. In this regartds, this study contributes a novel step in advancing the use of the EUFs into PD.

Then the questionnaire was validated with various academics with expertise in sustainable building design or ecological design, before delivering it to architects who are familiar with PD and ecological design who were able to provide valuable information which reflected their experience. Their responses were used to develop the UCPBD model which was used as a guide when designing the research questionnaire.

1.7 Study Assumptions

1. The architect should have knowledge to participate in this study.
2. The participating architects will provide answers that will reflect their experiences of practising PD and EU needs.

1.8 Significance of the Study

PD issues have been described as having to reduce using mechanical means and rely on the natural environment. Some of the definitions refer to the EU with regard to providing comfort for them or ensuring indoor air quality, which of course is for their benefit. There is no clear tool or theory that refers to considering EU needs during the PD process.

Even though it will be clearly significant if the architects understand that the EUFs could positively influence PBD, it is also important to evaluate the architects' assessment of the relationship between EU needs and the PDS. The result from this research will be a practical tool and theory for enhancing the delivery of PBD with considering EUFs within various ATTs, which of course can mitigate or eliminate the EU complaints.

1.9 Definition of Terms

User Centred Passive Building Design: a PD approach that places both EU and PDS at the centre of the design process for focusing architects' mind on EUs through the planning, design, development and operation of building assets.

Passive Design Human Attributes: Factors that capture the needs, wants and limitations of EUs in relation to functionality, performance, usability, flexibility, reliability and maintainability.

Passive Design Functionality is defined as: A set of design determinants that relate to the existence of set of PD functions (i.e. Ventilation, Lighting and Heating) that fulfil EU needs.

Passive Design Performance is defined as: A set of determinants that measure PD functions' performance under stated EU conditions.

Passive Design Usability is defined as: A set of ATTs that relate to operability and compliance of PDS to regulation standards and EU operational efficiency.

Passive Design Flexibility is defined as: A set of ATTs that relate to the ability of PDS to be remodelled to satisfy new use conditions.

Passive Design Reliability is defined as: A set of determinants that relate to the capability of PD functions to maintain their level of performance under EU stated conditions within the design service life period.

Passive Design Maintainability is defined as: A set of determinants that relate to the ease of inspecting, maintaining and modifying design to satisfy continuous evolving EU needs.

EU experience in PBD is defined as: The characteristics of the designed PB that enhance EU predispositions, expectations, needs, motivation, mood, etc, through the consideration of design constructs of functionality, performance, usability, flexibility, reliability and maintainability in a way that make the EUs feel in control of their living environment.

EU: The EU is an individual or groups of individuals who uses, in a permanent or temporary status, a building asset. This should be extended to take into account EU gender, age, ability, physical ability and psychology.

User: The Us are the stakeholders who participate in the development, design, construction and operation of buildings assets. These stakeholders' aim is to make the product possible for the EU.

1.10 Outline of the Thesis

The outline of this research is shown in Fig 1:1 and introduced as follows:

Chapter 1: this chapter provides an overview and introduction for this research, including justification for the emergence of this research, the aim and objectives of this research, research question, scope and limitation of this research, definition of terms and the research contents.

Chapter 2: reviews the historical theory since 1954 until today. This entails a thorough review of various trends of architecture namely modernism, post-modern, post modern ecology, traditional, late modern, new modern, complexity paradigm, sustainability and recent design approaches, trends and theories.

Chapter 3: presents a review about the notions of EU, UCD theories and standards (ISO 9126 and ISO 13407). It reviews the application of UCD theory.

Chapter 4: extracts the EUFs of PDHAs (Passive Design Functionality, Passive Design Performance, Passive Design Usability, Passive Design Flexibility, Passive Design Reliability and Passive Design Maintainability).

Chapter 5: proposes a UCPBD conceptual model. This is achieved through merging three compenents,which are PD dimensions - namely lighting, ventilation and heating - as the core of the model; the second component is the the design process; and the third component is the six PDHAs.

Chapter 6: this chapter reviews the research methods of research and development of the questionnaire through various stages. In addition to that, it discusses the advantages of using the questionnaire as well as the quantitative and qualitative methods.

Chapter 7: focuses on the findings of the data collection. It describes the highest and the lowest effective EUFs for each ATT through using the SPSS program using mean value and standard deviation methods.

Chapter 8: concentrates on the ranking of the questionnaire, finding the comparative of the ranking based on the S-ATT's level, each ATT level and the grouping of ATTs' level. In addition to that, the ranking was based on the architect experience level and professional role level.

Chapter 9: presents testing the hypothesis of the PDHAs based on both architect experience and the professional role and experience based on using one way ANOVA analysis. In addition to that, Tukey HSD Post Hoc was used to check the rejected EUFs. Further to that, it tested the reliability for each ATT based on professional role and experience of the respondents.

Chapter 10: In this chapter the most effective EUFs are refined by the researcher in order to use them in the proposed assessment tool. This was based on correlation of the EUFs. Then, the redundant one was identified to use in this research. This was achieved through using the SPSS program. After determining the most essential EUFs, they have been clustered in relation to their ATTs.

Chapter 11: The EUFs, which were extracted in chapter 10, are used to develop an assessment tool. Then it has been tested through 4 projects which are namely Houghton Street Project, Cherry Mill Project, Fitzroy Street Project and Tullis Russell Environmental Education (TREE) Centre. The testing was through the designers of these projects ranking the EUFs and calculating them with weight and without weight.

Chapter 12: presents the conclusion of the thesis, contribution and future research work.

1.11 Summary of this Chapter

This chapter introduced the research study by explaining the rationale of this study and the problem statements before moving on to declare the research problems, research hypothesis and both aim and objectives. Furthermore, this chapter discussed the study scope, the limitations of the study, and the assumptions of the study, together with its significance, before ending with a reference to the definition of terms which will be used.

Thesis outline

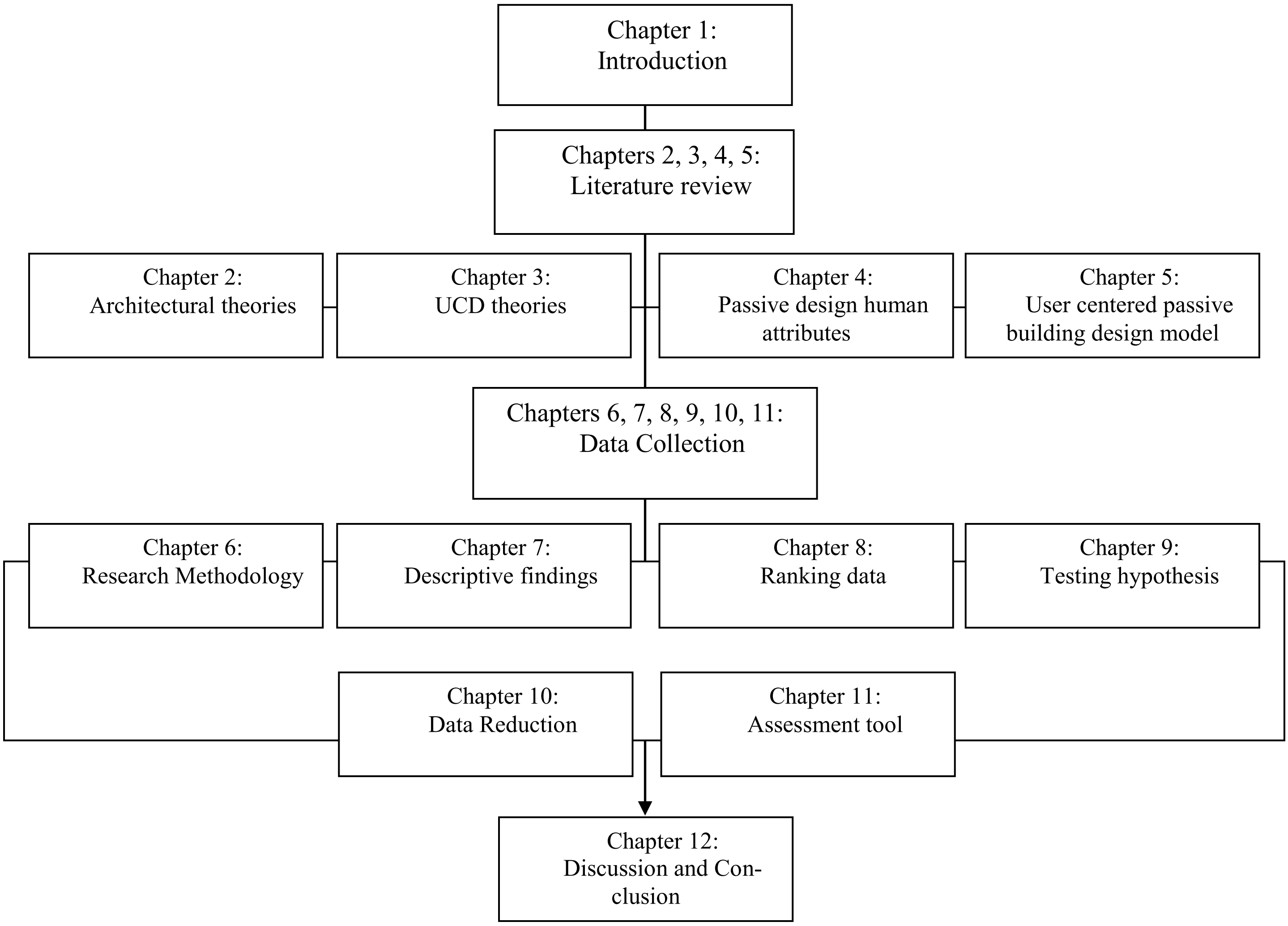


Figure 1:1: Thesis Outline

Chapter Two: Architectural and Design Theories and Trends

2.1 Introuduction:

The theory of architecture is an approach that reflects on the building design features. Generally, architecture is invigorated with technological revolution and environmental issues. The theory is an important benchmark of architecture since the previous decades. It is said that *"theory is an engine of architecture"* (Jencks and Kropf, 1997, p.8). This statement reflects the development of architectural practices. The building design approaches are an answer to and proof of that. The differences between architectural theories are a result of experience and the surrounding circumstances. The theories could be related to the trend of a specific period and could be related to a design process. The human is taking a place in some theories through consideration of their comfort or productivity and some theories consider the environmental issues. This research has reviewed the architectural theories since 1954 until the present. This procedure comprised looking at eight out of nine groups which are namely (modernism, post-modern, post-modern ecology, traditional, late modern, new modern, complexity paradigm, sustainability and recent design approaches, trends and theories). Each one of these groups includes several theories as will be explained in the following sections.

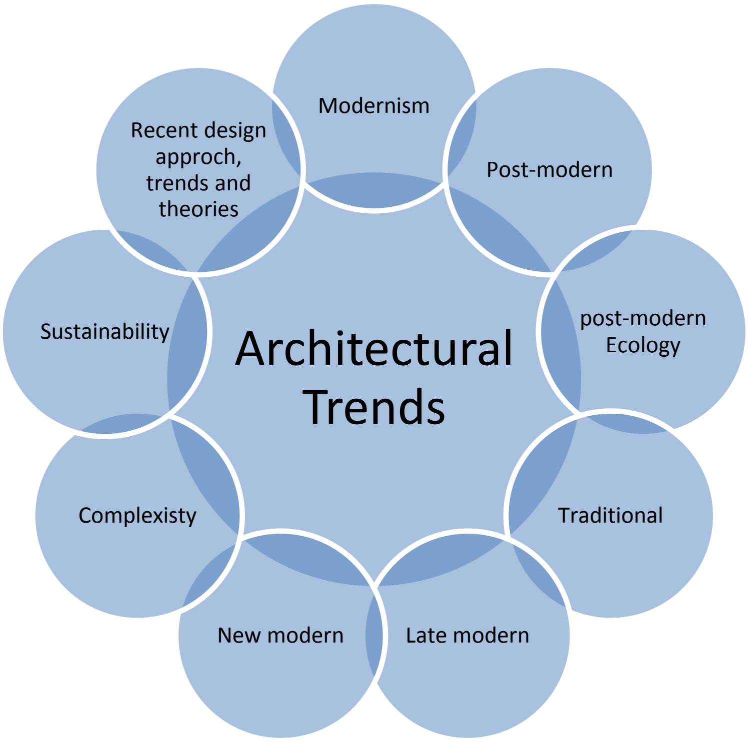


Figure 2:1: Architectural Trends

2.2 Modernism

Amir et al (2012) looked at modernism from different perspectives. The modern could be referred to as the thought or character or practice. In addition, this term describes a new art movement especially in cultural terms. This change happened between the 18th and early 19th centuries. Modernism is defined as *“a socially progressive trend of thought that affirms the power of human beings to create, improve and reshape their environment with the aid of practical experimentation, scientific knowledge or technology”* (Bermann 1988, p.16, as cited in Amir et al , 2012). In terms of the practice, which is one of the points that Amir referred to, Leach (2005, p.3) defined modernism as follows: *“Modernism is the aesthetic practice of modernity”*. Even though it considers the aesthetic, it still refers to changes and looking to new forms. This trend refers to the ability of changes and movement. Leach (2005) indicated how the social changes have been exposed to the modernist trend. This is an indicator that the modernist trend has an effect at a social level. This trend also refers to the link between functionalism and architecture, as a result, functionality has been considered in the conceptual model as a pivot compenent that could affect the rest design attributes.

2.3 Postmodern Architecture

This trend was started in 1950 last until the end of the 1970s. It began as an international style. This trend has returned to some principles of architecture such as ornament and wit. Some of the ideas of this trend can be seen already in architecture. It includes various theories, all of them placed around existing concepts. This appears clearly in the list already provided by Jencks and Kropf (2006) as shown in Appendix A. They include in this trend several theories such as the third typologies, the urban space and the architecture of complexity, ornament is not a crime, and other theories (see Appendix A). All of these theories are branches of and have been developed based on existing theories. These theories reflect differnces of architects’ perception. The architects in this period discovered the expressive architecture as well as the architecture elements. Leach (2005) indicated that postmodern cannot be classified as a new architectural trend: it is part of modernism. It is classified as an improvement stage for modernism. The architecture of postmodernism reflects the commercial developments in this period. This is obvious looking at the ornamentation of the architecture in this period. The capitalist and commercial period has affected this period and been part of its changes and the formation of some theories. This theory added two divisions which are decorative elements and ornamental. This concentrates on decoration. Using less grid shape and sculptors are reacting to the simplicity which has been referred to in the previous theory. This theory gives a new looks for the buildings through adding decoration; it also gives movement for the buildings better than the grid feature. The building form has become more playful. There are various architects who were within this trend such as Frank Gehry, and Richard Rogers (Dudley, 2012). Postmodernism as a trend was against many trends of the modernist theories. This theory is distinguished though creating a mix between the traditional and new forms. The building shape was form in unanticipated ways. The building symbols were simple. The theory also included contradiction and complexity in architecture (About.com, 2012). This trend was distinguished by several theories that related to different levels of design details, building and urban, as appear in Appendix A. Some of the theories and principles of this stage could be included in the proposed EUFs for fulfilling EU needs.

2.4 Postmodern ecological

Jencks and Kropf (2006) have listed several architecture manifesto and theories. The theories of this trend were formulated between 1969 and 1996. The list introduced the interaction between ecology and postmodern. This is obvious in several theories. One of the theories is design with nature. This theory was coined by Ian McHarg in 1969. This theory refers to the need to consider environmental issues. There are several criteria that have been indicated in this theory which are negentropy, apperception, symbiosis, fitness (fit ecologically), and pathology (relate to health). This theory looks at how to group various principles to drive the design, method and ecology at the same time. The human need has not taken a clear place within this direction. However, some of these principles could be considered to match EU needs with PD. Sim Van Der Ryn (1979) coined the term integral design theory. This theory is an interaction between natural systems and the environment. The aim of this application is for people's benefit. This trend is called bio architecture and ecotecture. The latest one comprises human system design which includes functionality, aesthetics and the natural ecosystem. This feature could be taken into account when bridging the gap between the PD and EU needs as introduced in the research problem of this thesis. Hassan Fathy (1986) is one of the architects who considered the ecological issues. Jencks and Kropf (2006) referred to the theory Natural Energy and Vernacular Architecture which was coined by Fathy. In this approach, both human and ecological needs have been considered. In terms of the human, buildings have been constructed that fit with their life styles, because this design is for lower class people. Consideration of their local culture (vernacular traditions) as well as local materials that could be reliable to face the environmental issues was required. Considering the traditional style for building is part of consideration of EU needs. These principles should be taken into account when suggesting the factors that should be considered as EU needs.

2.5 Traditional

The majority theories of this trend are concentrated on the traditional style. This trend to some extent is part of the historical trend. Consideration of the principles of traditional theories appeared in the theories of this period. The theories of this period were developed between 1969 and 1994. Hassan Fathy (1969) (as cited in Jencks and Kropf, 2006) developed the theory of architecture for the poor. This theory concentrated on the traditional methods and forms of construction, and has been adopted to accommodate the society's needs. Looking to the local and traditional methods is required to fit the EU circumstances. Some of Fathy's principles could be taken into account to meet EU needs, which is the aim of this research. The value of the traditional theory was coined by Robert Maguire (1976). This theory concentrates on combining the zeitgeist with the historical. It can be interrupted as integration of the traditional with current life trends. This is a kind of mixture of patterns. This idea could be classified under accommodating changeability. This could enhance the EU needs in case they prefer to improve or interact with a new style. The theories of the traditional trends are centred on traditional issues. Demetri Porphyrios (1983) stated that classicism is not a style. Classicism can be defined as *"symbolic elaboration of vernacular".* This theory is focused on simplification of the building form and its features. The style of the form and building is one of the essential elements of the buildingwhich could have a clear effective on meeting EU aspirations. This will be considered by the researcher during bridging the gap between PD and EU needs. One of the theories in this period is architecture and theology which made by Quinlan-Terry (1989). This theory shows the relationship between architecture and religion. Taking into account respecting their faith is part of considering EU needs. However, in case considered faith as EUFs will be related under culture EUF. This is also some other theories which will be introduced in the Appendix A.

2.6 Late Modern

The period of this trend was also between 1954 and 1994 as Jencks and Kropf (2006) listed. Pile (2005, p.422) defined late modern as *"An alternative theme in recent design rejects the characteristics of post-modernism in favour of continuing loyalty to the concepts of earlier modernism. Late modernism describes work that does not imitate that of the modern pioneers, but that moves a head in ways in which they might have been expected to develop their ideas if they were still actively involved in designing buildings".* This trend shows a new route that does not agree with the ATTs of postmodernism. However, it is more related to the the modernism trend. Still this trend has its own philosophy which leads to avoid repeating the modernism. Some of the theories of this trend are indicated by Jencks and Kropf (2006). The new Brutalism as theory was coined by Alison and Peter Smithson and Theo Cosby (1955). This theory is concentrated on the form. This theory also can be classified as symbols building. Selecting a building form does not take into account the human factors. This theory is reflected in the style of the buildings made from rugged reinforced concrete which is cold Brutalist. It is reflected in the rough and concrete building. This style is also heavy and angular. It is distinguished in that it can be constructed quickly and economically. There are several features such as "Precast concrete slabs, Rough, unfinished surfaces, Exposed steel beams and Massive, sculptural shapes" (About.com, 2012). This reflects four main areas; material, style, quickly and economically. Some of them reflect the human factors and some do not; however, it still does not reflect EU needs as the main concern of EU centred PBD which is EUFs as central to all of them. This theory also deals with building form and style as part of PDF: to be providing to support building function in a way that enhances EU needs. Silence and light is one theory that is related to this period, which is made by Louis I Kahn (1969). This theory is related to need for the space to be quiet and light. This theory considers the comfort factors of the space. The question could be asked, it is for humans? The simple answer is yes but the EUFs should be in the designer's mind as the axis of the design process. This has been fulfilled through considering various EUFs such as acoustic conditions or considering EU privacy. Non plan theory is a theory that was coined by Credic Price (1969). Non plan is intended to destroy such a system value. Give the possibility to society to change prioritise the regulation. It is enhanced to change and redevelop forms or activities that are not realized. The end result might not be as we want but it could still be positive. This theory seems to avoid the restriction of plan forever. The human factors were considered as part of it. However, it was not in various ATTs or central to architects' thinking. Also, adaptability in flexibility and usability has solved this issue through responding to changeability and future changes. The theory of this period includes several EUFs that could be considered as EUFs.

2.7 New modern

Occurring between 1976 and 1994, the theories of this trend have been listed by Jencks and Kropf (2006). The architects' interests in this period were various; some of them concentred on the issue of functionalism, which is also indicated by some architects in some of the previous trends. Peter Eisenman is a good example. The theory that was coined is post functionalism. This theory is an attempt to move from cultural to modernist. This is opposite the humanist to modernist, which means opposite the function and the form. The volumes of theories of this trend include many aspects. With regard to the EUFs, this theory ignored the humanistic system. Considering EU issues with bridging to PD is the main purpose of this research. However, the issue of functionalism could be part of the EU requirements that need to be investigated. Bernard Tschumi (1977) is one of the architects of this period. The theory focused on the pleasure of architecture. This theory considered the EUFs by stating that the architecture should reflect what the EU desires. This theory is not related to PDHAs. Pleasure is a wide terminology that should be specified to several criteria such as in terms of human, aesthetic or environment. Considering the issue of the future was one of the features of this period. This is obvious in the Coop Himmelblau (1978) theory, the future of splendid desolation. It refers to the three main aspects: efficiency, economy and expediency. It also reflects the view that architecture is hiding the problem instead of creating awareness. It also believed that the main reason for desolation is the act of using. One issue that was considered in this period is space, via the theory of end space, which was coined by Daniel Libeskind (1979). Libeskind tried to use drawings and text to explore the tensions between various aspects as follows: "*experience, intuition and formalisation, the voluntary and involuntary"*. He considered that there is not a clear indicator regarding the involvement of human factors in this method. This is an approach that relies on the design method as well as the options that the designer should have to use in his design. This theory should be taken into account in the theory proposing a process that enhances EU needs.

The changes in architectural trends and philosophies during this period were phenomenal. This is made obvious by Coop Himmelblau's (1980) philosophy. Architecture Must Blaze was coind by Coop Himmelblau's. This philosophy is said to be creative. In order to achieve this, manifesto said that the architecture should be smoother, hard, dreamy, and colourful; up lighting are some of their features. This theory attempts to illustrate that the architecture needs to be more distinguished in different ways. This theory paid a clear attention to aesthetic trends. This is part of the architectural requirements. The aesthetic is related to PDF. However, meeting end user needs should be the most essential requirement during the design process. EU needs should be the top priority for the designer.

2.8 Complexity paradigm

Jencks and Kropf (2006) referred to this trend when they listed the most famous theories between 1977 and 2005. The theories of this trend are various. The fractal geometry of nature is one of them, which was coined by Benoit B Maandelbrot (1997). This theory is related to consideration of the family of shapes or geometry as the mathematics makes different shapes fractal and not related to nature. In this theory, Benoit (1997) said that he investigated this theory in order to avoid formless geometry. This was through relating nature to the shape. In a simple sense, this theory considered geometry dimensions, regularity and irregularity. The issue of building form and geometry is important in any design. One of the theories in this period is Fringe Cringe which was made by Howard Raggatt (1991). This theory looks to express the situation of the architecture of Australia not being the centre; the American and European canon has been the centre instead. This theory considers the effectiveness of colonial legacy on the architectural style and law. It is about the effectiveness of other cultures in the local culture. Considering the culture is one of the most important issues related to EU needs. Still, meeting EU needs is not a clear demand in this theory. Michael Batty and Paul Longley (1977) created the fractal city theory. This theory is related to cities' form and scale. The fractal law could form the cities at every scale. The new trend is to design a city that copes with the technology. Diagrams theory is coined by Ben Van Berkel and Caroline Bos (1999). It is a method of design that helps the designer to liberate the architecture from three points, namely signification, interpretation and language. This method is similar to abstract art. The technologies affect this stage and make it an animated form theory. This theory was adopted in 1999; it concentrates on the idea that architects can deal with animation through using computer methods. It is related to the view that benefits from technology can improve the contemporary architecture.

2.9 Sustainability and beyond

This trend deals with the environmental issues; to maintain the resources so that they can serve the next generation. It is also concerned with the quality of life and effect of pollution (Mallgrave and Goodman, 2011, p. 215). It is almost thinking of the built environment. There are various theories that have been related to this period, which have been referred to by Mallgrave and Goodman (2011) as follows.

The green movement is one of the theories that have been listed by Mallgrave and Goodman (2011). This theory concentrates on using clean energy efficiency as the main environmental concern. Sustainable development is defined as *"meets the needs of the present without compromising the abil-*

ity of future generations to meet their own needs" p.217. Wheeler and Beatley (2004, p.54) stated that *"The time has come to break out of past patterns. Attempts to maintain social and ecological stability through old approaches to development and environmental protection will increase instability. Security must be sought through change"*. Based on these definitions, this trend concentrates on the current social, environment and economic issues, on one hand. One the other hand, the future issues have also been considered in this definition, which could also be considered in this research. This trend is related to the issue of sustainability and environmental issues. However, it is at the building scale. It extends the issues of environmental effects to be an international code for building. In 2003, the European Union issued the energy performance of building directive (EPBD). This led to the creation of other tools such as BREEAM, LEED, and CASBEE. It also deals with energy consumption as well as indoor air quality. These interests take part in this study in order to bridge the gap between EU needs and PD. These interests play an essential part in this study. The PD issues are related to green building. Both are trying to achieve the same aim.

Mallgrave and Goodman (2011, p. 215) also referred to the Biophilic design. Julie Stewart-Pollack, ASID, IDEC (2006) defined this trend as *"Biophilic design recognizes the inherent human need for nature together with sustainable and universal design strategies to create environments that truly enhance life"*. This theory refers to how people respond to an environment. This also considers the psychological, physiological, neuroscience, health and well-being of humans. The landscape could lead to reduce stress and blood pressure, and have notable health benefits. For example, in a hospital room with a view of a landscape, patients usually complain less. This trend also concentrates on water, fresh air, sunlight, plants, and views of nature, accessible green spaces, architectural scale, proportions, materials and ornamentation. The difference between this study's proposal and this trend is the design process as well as the classification of PDHAs through which EU needs are integrated. This reflects on aesthetic judgment which covers visual training, the human gender, meaning of objects, emotional variables, and culture and changing fashions. It is referred to as *"human art behaviour"*. It is referred to in traditional architecture as rhythm, scale, order visual complexity and ornamentation. The variety in this approach is for aesthetic and environmental interests. These interests could be considered as a part of EUFs that could be used to meet EU needs.

2.10 Recent design approaches, trends and theories

Attaianese and Duca (2010) referred to four recent approaches which are usability measurements for building, ergonomics and building design, building use in design management perspective and buildings' accessibility and design for all. Also, there are several theories that refer to history or building elements. There is also another trend that considers the current issues. A usability measurement for buildings is one of the recent approaches. The concept of usability is integrated into designing buildings for human purposes. It is conducted through (Alexander, 2010). Blakstad (2010) referred to usability as buildings that support EU activities and physical surroundings through contributing to them with efficiency, satisfaction and effectiveness. The USETool has been determined as a tool to evaluate the usability of the workplace. Usability could be a process, as argued by Fenker (2008, as cited in Blakstad et al, 2010) and could refer to social construction. It is defined as follows: *"... given that they are designed for one or more activities, the artifacts are bearers of a set of possibilities and constraints as well as, most importantly, activity and social practices models."* The activities and social practices of the EUs clarify the importance of the usability. As has been stated, it is designed for more than one activity. Blakstad (2010) said that usability covers three main points as follows: firstly, specified buildings enable EUs to achieve their needs. Secondly, the importance of the building context, will lead to determining the dimensions of the relationship between building and EUs. Finally, EU satisfaction and value creation contribute to the usability to achieve a specified goal. These three points reflect to the researcher the importance of identifying the EU, whether they are visitor, worker, resident, and their age and abilities. The second point is the building type where the usability requirements for a school are not similar to those for an office building or residential building.The final stage is meeting EU needs to the satisfaction of the user. EU needs could be considered without achieving a high level of satisfaction, such as providing functions that are not suitable to EU abilities. Blakstad (2010) related EU experience to space design as one of usability's determinants. For this reason, the spaces should be well-functioning to be as EUs wish. This theory to some extent is focused on usability and its imporance to be integrated into building design. This theory is distinguished because it considers human needs as well as their satisfaction and activities. One of the recent theories is post-occupancy evaluation (POE). The post-occupancy evaluation as a theory considers the EU needs through including physical, technical and psychosocial aspects and evaluations. POE is: *"... the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time"*, according to Preiser et al (1988, as cited in Blakstad, 2010). So this definition reflects the importance of EU perceptions after using the building. This theory is an assessment for EUs after they have occupied the building.

Issues learned from the literature	Argumentations	Research gaps	Research Questions
Is there an architect who has proposed a theory that meets EU needs in related to PD?	As per the literature review discussed in this chapter, there is no architect proposed a theory that meets EU needs in relted to PD?	There is a need to propose a theoretical model that relate EU needs to PD.	What is the conceptual model that interact EU with PD?

Table 2-1: The issues learned from the literature

2.11 Summary of this Chapter

From what has been reviewed above, it could be concluded that the variety of design theories is reflected in the development of architectural design theories over a long period of time. In addition, the various architectural trends clarify the different architects' interests. These theories involve various and different issues that could be considered to fulfil EU needs. Some of these theories are related to ecological issues. However, there is not a theory that includes criteria that could relate EU needs to PD, which is the problem and the gap that this research aims to address. In a way, the EU needs become the main driver for designing PD. The design process comprises PDS and PDHAs that helps the designer to ensure the EU needs have been met or not. The contents of these theories could be used as EUFs.

Chapter Three: User Centered Design Theory

3.1 Introduction:

Integrated EUFs can play an essential role in the design process; in order to do so the suggested model should hold several ATTs to be central to PD. In this chapter, the researcher will review a UCD theory for integration of EUFs by various ATTs. UCD will be used to develop the model in this research. However, the notion of the U should be reviewed. For this reason, this study will start this chapter by reviewing the U notion in order to understand who the EU is, as this research is trying to propose a model that will satisfy the EUs' needs. This will be reviewed in detail in the following section before discussion of the UCD theory.

3.2 The Notion of the User

The term EU refers to the individual(s) who interacts with a system or any other product, as cited by Ågerfalk (2001). The research to date has tended to focus on building occupants. However, far too little attention has been paid to identifying and categorizing the building Us and EUs. A considerable amount of literature (mainly in domains outside the construction industry) exists on the definition of U. Geumacs (2009, p.29) classified the U into three main categories, as shown in Figures 3:1 and 3:2. The first type is direct Us, defined as *"people who could use directly the software"* (Geumacs, 2009, p.29). To be more appropriate this type of EU ought to be called the actual EU. The second type is indirect U, which is defined as "*people who would not be involved in its direct use but whose inputs and decisions may have influence on the features of the platform should present"* (Geumacs, 2009, p.29). The definition emphasizes the U who can play a role in designing and forming the product aspects. This includes the product designers and other key design stakeholders. To be more appropriate this type of U ought to be called the influential U (i.e., stakeholders who participate in the development of the product on a temporary basis). The last type of U is referred to as other stakeholders which is defined as: *"people and organisations who are at different levels involved in the development of the platform and/or whose participation and input are needed for the development of the platform (in our case: consortium members"* (Geumacs, 2009, p.29). The definition encompasses all decision makers who might be able to influence the development of the software or product in one way or another, and they can be described as peripheral Us (i.e., organisation or individuals who have an indirect stake in development and use of the product). In this classification the U has been identified based on their close

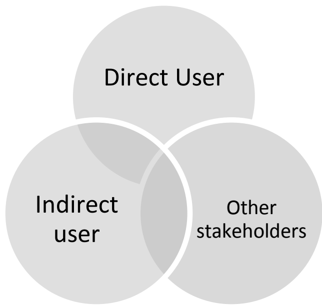


Figure 3:1 The user type

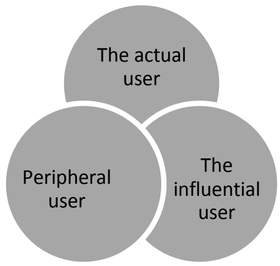


Figure 3:2: The classification of the user type

proximity to the product and on the role they perform during the development and usage of the product. The U in the software industry is defined as *"Professional programmers and domain professionals [who] define the endpoints of a continuum of computer users"* (Fischer, 2009, p.5). In this definition the programmer and other software stakeholders are classified as the U. The U in this definition is classified in a broad scale. The definition did not classify or categorise the type of Us. This research postulates that categorizing U and EU into homogeneous groups should be clearly defined and articulated. Understanding the U categories will assist in the elicitation of their needs, thus allowing the designer to specify and design a product that reflects their aspirations. Nardi and Miller (1991) classified EU into three sub groups (as cited in Dorner, 2010, p.11-12): "e*nd users have little or no programming education and a lack of intrinsic interest in computers"*. The EU is defined as someone who is not expert in using a computer. This definition concentrates on the U knowledge and experience of the product being used. Thus, this type of U is classified as micro U experience. The second type is labelled as *"local developers are domain experts, but no professional programmers"*. This is the meso EU who has some basic knowledge about the product. The final type of EU is macro U experience which is described as *"professionals have much broader and deeper knowledge of computing than local developers"*.

These definitions classified the EU based on the criteria of experience and knowledge about the product being used. It is proposed to classify them into three main categories (i.e., Micro, Meso and Macro) based on the criteria of knowledge, experience and proximity to product development and usage, as shown in Figure 3:3. The last type - macro U experience - is similar to the super U concept suggested by Morch and Mehandjiev (2000, p.76, cited in Dorner, 2010, p.12) *"advanced end users who have accumulated considerable expertise in local (in house) development and* tailoring. *They provide help and guidance to other users and they train these users to participate in end-user development activities"*. In this quotation seniority in knowledge about the product plays a pivotal role in classifying EUs. Huang et al (2003) defined U as: *"user (symbol as user) is the role which uses the grid system"*. The Grid system is defined as set contents that assemble in groups and each content is called a node (Huang et al, 2003). U is managed only by its owned node, not by the entire Grid. *"And it may be the same user which belongs to owned node before the owned node joins the Grid system"*. This definition explains the relationship between the U and the software grid. The idea here is that the U task can be considered based on some ATTs, not all design ATTs. The Business Dictionary (2012) defined U as an *"Entity that has authority to use an application, equipment, facility, process, or system, or one who consumes or employs a good or service to obtain a benefit or to solve a problem, and who may or may not be the actual purchaser of the item"*. In this definition the U can be direct or indirect. The U could be the one who buys, consumes or employs a product. Another definition for the EU by Whats-Come (2008) is:

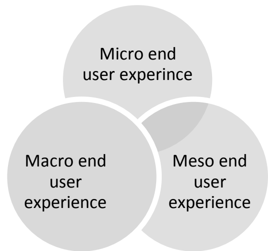


Figure 3:3: End user experience

"In information technology, the term end user is used to distinguish the person for whom a hardware or software product is designed from the developers, installers, and servicers of the product. The "end" part of the term probably derives from the fact that most information technologies involve a chain of interconnected product components at the end of which is the "user." Frequently, complex products require the involvement of other-than-end users such as installers, administrators, and system operators. The term end user thus distinguishes the user for which the product is designed from other users who are making the product possible for the end user. Often, the term user would suffice". It is very clear from this extract that there is a distinctive difference between U and EU terms. The distinction is based on the proximity and type of involvement that the Us might have in the development and usage of the product. The difference also draws on experience and knowledge criteria stated in the previous definitions. it is probable that the criteria of EU and U contained this extract are very relevant to the theory of UCD in construction industry.

Webopedia (2012) defines the EU as *"an individual who uses a computer. This includes expert programmers as well as novices. An end user is any individual who runs an application program"*. This defines the EU as everyone who could interact with a computer program. EU terminologies in software engineering are explained by Ko et al (2008, as cited in Burnett, 2009, p.16) as *"end-user programming involving systematic and disciplined activities that address software quality issues (such as reliability, efficiency, usability, etc.). In essence, end-user programming focuses mainly on how to allow end users to create their own programs, and end-user software engineering considers how to support the entire software lifecycle and its attendant issues"*. The interrelation behind the content of the definition is the linkage between the EU experiences and the quality of the designed product. The authors here relate the endeavour of the designers to how they respond to EU needs in terms of usability, reliability and efficiency. The statement also advances the importance of the product life cycle issues and how the EU should be able to design their own products to reflect their unique needs. These issues are also pointed out by Wikipedia (as cited in Burnett, 2009, p.16) when they defined EU development as *"end-user development (EUD) is a research topic within the field of computer science, describing activities or techniques that allow people who are not professional developers to create or modify a software artefact. A typical example of EUD is programming to extend and adapt an existing package (e.g. an office suite).* Law et al (2008) cited various definitions of U experience. According to Alben (1996) U experience is related to "*all the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they're using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it"*. The Nielsen-Norman Group defined U experience as *"all aspects of the end-user's interaction with the company, its services, and its products"*. Wikipedia (2012) stated that *"user experience is a term used to describe the overall experience and satisfaction a user has when using a product or system"*. Mäkelä and Fulton Suri (2001) presented U experience as *"a result of motivated action in a certain context"*. Hassenzahl and Tractinsky (2006) defined U experience as *"a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.)"*. It can be seen from these quotations that the importance of U satisfaction is cited in many publications as the main construct for U experience factors. Us' experience deals with the quality ATTs of the product. It assesses whether or not the product fulfils the Us' needs. U experience is sometimes measured by the number of complaints that Us raise in relation to the product usability and functionality. All of these points are of paramount importance in the design of building assets and they should be considered in the framework for UCPBD.

Various terminologies in the building industry are used to describe the U and EU. These include terms such as occupant, resident, tenant, owner, client, etc. The Free Dictionary (2012) defines the occupant as "*One that occupies a position or place ".* This suggests people who live in, reside in and inhabit a space. This view is further defined by the Free Dictionary (2012) as "*One who has certain legal rights to or control over the premises occupied; a tenant or owner"*.

There are also various other terminologies such as citizen, dweller, habitant, inhabitant, and in-dwellers, which are defined as *"a person who inhabits a particular place".* These definitions mainly deal with residential buildings. The term tenant is defined as *"any occupant who dwells in a place"*. The Free Dictionary defines residence as **"***a person who lives or has his home in a particular place".* It is also defined as *"living or having one's home in a place"*.

It is very clear from the above literature that there exists a difference between EU and U. Hence, using the evidence in the literature review, this study has classified the building design U into EU and U. The Us are the stakeholders who participate in the development, design, construction and operation of a building's assets. Their aim is to make the product possible for the EU. The U is an individual or groups of individuals who use, on a permanent or temporary basis, a building asset. This should be extended to take into account EU gender, age, ability, physical ability and psychology.

Figure 3:4 relates the U to the design ATTs based on the level of their interaction. The U (such as the maintenance personnel and technicians) is more related to the last three ATTs. This can also be classified based on their level of interaction. Thus, the relationship between the EU and the maintainability, reliability and flexibility is very limited in terms of the time and use. For this reason, the U is more appreciative of these ATTs. In addition to that, the user's level of experience is one of the most essential demands for the U. For this reason this study has not paid much attention to their age, psychology, or gender because their interaction level is less than that of the EU. The EU should be considered based on their age, physical ability, and whether or not they have a disability. Gender is also considered an essential EUF during the design stage. There is a fluctuation in the U and EU role based on the future construction stage. The EU interacts with the functionality performance and usability ATTs more than the other ATTs.

For U experience in the PBD process, this study has adopted a definition based on Hassenzahl and Tractinsky (2006). Their definition includes all of the ATTs shown in Fig 3:4. In addition, it includes issues such as the U context, the design ATTs, the context of design use, and their interaction with each other. The EU experience in PBD is defined as: the characteristics of the designed PB that enhance U predispositions, expectations, needs, motivation, mood, etc, through the consideration of design constructs of functionality, performance, usability, flexibility, reliability and maintainability in a way that make the EUs feel in control of their living environment. It is clear from the adopted definition that the characteristics of the designed PBD that are based on the design constructs are the basis by which the EU needs are identified and integrated into design. The next section of this chapter will discuss and explain the theory behind these processes. This study will use the EU type to consider the argument and design requirements.

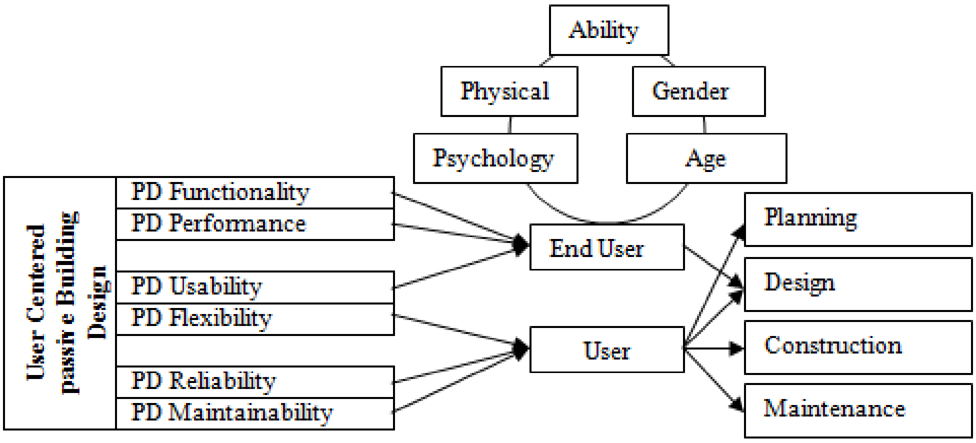


Figure 3:4: The relationship between the EU and U with life cycle design project.

3.3 User Centred Design theory and background

This thesis posits that the UCD theory is the most suitable approach to bridge the gap between EU needs and PD. The UCD theory stems from software design in computer science and information technology. The purpose of establishing this theory is to promote U needs when designing software. The theory is defined as *"UCD is a broad term, used to describe a design philosophy and a variety of methods in which the needs, wants, and limitations of end users are placed at the centre of attention at each stage of the design process*" (Uckelmann et al, 2011, p.68). The ability of the EU to manipulate the product to suit their purposes is described as "*users are able to customize and adapt the software systems in use to their particular needs at hand, so that they can perform their work more efficiently and effectively"* (Prähofer et al., 2002, p.1). This theory has also been applied in various fields, as will be illustrated in the following sections. This was one of the motivations that encouraged the researcher to adopt it in PBD processes.

3.3.1 Application of user centred design theory

UCD was introduced as a theory for the designing of software. It was introduced as a process which helps the Us to be involved in the design process or at least to be asked to specify their aspirations. The theory is also used in other fields. Some of its applications are described in the next sections.

3.3.1.1 Applying UCD in Education

Education is one of the fields where UCD has been used extensively, as stated by Kahraman (2011). It is employed in developing education courses. The process used in this type of application is as follows:

Students as Us are used as experimental tools in the development of the course by the tutors, who, in this case, are the designers. Students give feedback about the modules when they receive positive and negative attitiudes from the tutor. This interactive and dynamic relationship is viewed as one of the best methods for developing online courses.

Specify the context of use: The UCD approach was used to redesign three modules of interior design at the School of Architecture in Cankaya University. One of the three courses was ‘social and cultural factors in design’ which is about the interrelationship between cultural, dynamic and physical settings. The UCD was also used to elicit the U needs and satisfaction in interior architecture. The last course was urban design. The design of this course also followed the same pattern.

Two methods were used to which are focus groups and questionnaire. They were used to allow students to identify their needs and expectations. The first methods used three questions. These are (Kahraman, 2011):

- What are the factors which increase learning ability on courses?
- What are the factors that might increase your success on the courses?
- If you were the teacher or lecturer for this course what are the best methods to increase the success of your students?

The questionnaire included the following questions:

- What do you think about the content, teaching method and the tutor of the course?
- What is your satisfaction about the course: please evaluate from 5 to 1 as maximum satisfied to minimum satisfied?

The above method shows that questionnaires can be used to evaluate products that are designed based on UCD methods. This is will be further investigated to examine if a similar method could be developed to assess this proposed model.

The findings of the data from the previous steps were collected and analysed. The results from this exercise were used to redesign the courses. The findings were summarised in five main points. These are: (1) the student asked to practice what they learn in the class, (2) the support of friendship between the lecturer and the student, (3) the communication between both the tutor and the student must be continuous, (4) Memorising the course is through visual association rather than memorising it at heart and (5) it is important to remember the course through other methods such as visual association.

A design solution was presented in visual media and focus groups and it was evaluated through eight categories. These are: (1) discussion in the class, (2) using the visual media to present the subject, (3) creating an exchange relationship with students, (4) discussion of several subjects and their relationship with the design, (5) Change the course in a way that does not demand the student to memorise it by heart , (6) providing examples such as from Ankara, (7) motivating the students to express their feeling and (8) participating in the course including group work, which is increasing learning ability.

The result showed that, 92% of the students were satisfied about the course. This is a very significant result which demonstrates the usefulness of the UCD approach when utilized to develop the courses. Thus, using UCD in this instance has resulted in Us' satisfaction and improved their productivity, i.e., assessment results.

3.3.1.2 Applying UCD in the Swedish National Union Catalogue

Lindström and Malmsten (2008) used the UCD approach to rebuild the Swedish National Union Catalogue. They followed some of the ISO 13407 processes as shown in Figure 3:5. The design process was iterative and at the same time the group project was formed from several sectors such as engineers and designers, and so on. The Us were part of the process. Various methods were used to make the Us participate in the process. The methods were survey, usability testing and focus group. In addition to this, interviews with several categories of Us such as researchers and library workers were used.

Survey method:

Understand and specify the context of use is the first process in ISO 13407 as shown in Figure 3:5. The survey and focus group methods were used to extract the context. The survey technique used was multiple choice and open questions. The questionnaires were about the old version of LIBRIS (The Swedish National Union Catalogue of the National Library of Sweden). The survey helped to develop and improve LIBRIS through use of open questions which gave the users a free area in which to express their ideas.

Focus group:

The main task here was to gather qualitative data. The approach included two routes; the first was to record the U behaviour. The second was workshop groups to discuss the positive and negatives aspects of the design and make suggestions.

These two examples and others such as [interviews, workshops, field studies and usability testing] have used the UCD design theory to ensure that the designer can empower the U to participate in the design processes without any conflicts. The theory is also used in other sectors such as telecoms, health care, dentistry and so on. The wide use of theory is evidence of its capability to capture and integrate Us' aspirations into design processes. Because of this characteristic of this method it has being chosen for eliciting EUs' design constructs in PBD processes.

3.3.1.3 Applying UCD in Architecture

Any building is a process of design which starts from the concept and ends after recycling. This is demanded to consider by the designer as well as the U role during whole life cycle. Bullinger (2010) has referred to the complexity of the building. Also, it has been added that the classical methods cannot help to avoid the complexity of design. The authour related that to two main categories: communication and data management. One of the reasons for looking at communication is participation of the EU. Usually, the designer does not seek the participation of the U during the design process. Bullinger (2010) added that UCD has not been integrated with the building process. For this reason, it has been used it for meeting the future requirements of the Us. This has been distinguished when they refer to the various kinds of EUs such as EU, technical manager, contractor, temporary visitor, architect and facility manager. All of them should participate in the design process because all of them have special requirements which should be met in the design. This could be through work on one building model as a prototype to involve what they want, and then identify the various prototypes and discuss them with the contractor and U. The 3D model could involve U needs, visualisation, components, behaviour of the building parameters and system.

These various examples and others have been involved in the UCD design theory to ensure that the design can empower the Us to use it without any conflicts. This theory is not limited to the previous fields. It is added to other fields such as telecoms, health care, dentistry and so on. This gives a clear indicator about its possibility to be applied to any field to improve Us' performance when they deal with it. The latter example also gives a sign about the possibility about its application in buildings. The literature review shows that the theory is used to develop some of the ISO standards, such as ISO 9126 and ISO 13407. These standards are designed to enhance the integration of U needs into software design. Because of their importance to this research work they are reviewed briefly in the following sections.

3.3.2 ISO 13407

This standard illustrates the process that helps the designer to integrate U needs through the design process. The process is divided into several stages, as cited in ISO 13407 (1999) and shown in Figure 3:5.

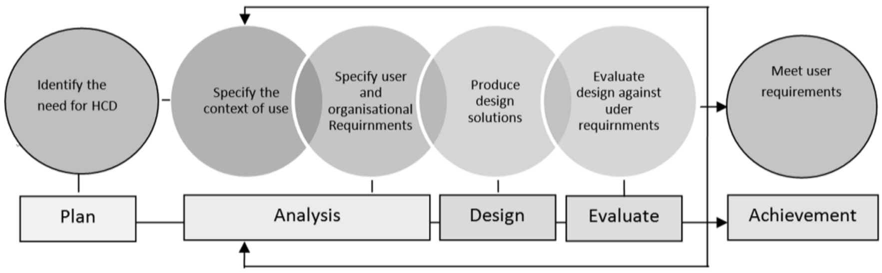


Figure 3:5: ISO 31407 process (ISO 13407, 1999, p.6)

The process of ISO is summarised by Jokela et al. (2003) as:

- *Specify the Context of Use*: This stage consists of three main areas, starting by identifying the U, usage environment and the purpose for using the product.
- *Specify User and Organisational Requirements:* This will be through identifying the factors that can help a U to be able to carry out their task when they use the product in a quick way without any barriers. The stage aims to determine the design line requirements.
- *Produce Design Solutions:* That is to say, creating a solution for a product based on factors such as usability ATT.
- *Evaluate Designs Against Requirements*: answer the question to what extent the end product measures up against U assessments.

The above key processes are the main core of the UCD theory. The first stage is to assist the designer to manage and plan the design process and define the context of building asset use. The second phase is directly related to extracting and organising U requirements. The subsequent stage is for the designer to derive a possible solution that satisfies all of the U wants and wishes. In the last stage the designer needs to verify if the proposed solution or product satisfies and meets U requirements. If the requirements are not met then, ultimately, the designer needs to go back again to specify the context of use and go through the design processes until the EU wishes are fulfilled. Following this the design paradigm will ensure that the U needs are met before delivering the end product. To meet the EU requirements a raft of ATTs are normally considered and evaluated by the designer at various stages of design. ISO 9126 has been developed to illustrate how to incorporate EUFs, through various ATTs, into the design of software. The importance of this process is explained in the following section.

3.3.3 ISO 9126

This standard is conceived to promote the quality of software design. The standard is defined as "*a software product quality model, quality characteristics, and related metrics*" (Zeiss et al., 2007, p.2). ATTs are shown in Figure 3:6. The standard includes six ATTs that are composed from several S-ATTs.

The model is mainly based on quality in use of ATTs. The quality in use is defined as "*the quality perceived by an end user who executes a software product in a specific context*" (Zeiss et al, 2007, p.2*)*. The focus of this definition is on the necessity to consider U needs into the design product in a specific context. This model is developed based on six main ATTs and their S-ATTs as shown in Figure 3:6.

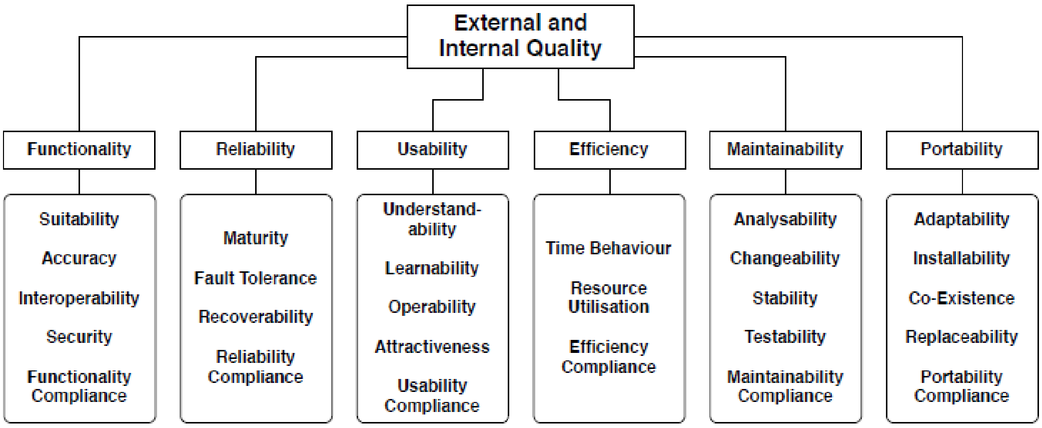


Figure 3:6: External and Internal Quality ISO 9126 (Padayachee, 2010, p.3)

The main ATTs are Functionality, Reliability, Usability, Efficiency, Maintainability and Portability. ISO 9126 is adopted to develop the UCPBD model. Because of the importance of these model components to this study, they are explained in the following sections.

Functionality:

The definition of design function is different and several based on what is its field and application. For this reason, to define the PDF is to understand and clarify what is the function. There are various definitions of function as follows. The Business Dictionary (2011) defines the function as *"An action performed by a device, department, or person that produces a result"*. It can be seen clearly that there is a clear relationship between the design for functionality and the design for performance. Also, another indicator is the person and how the EU can affect the design function, as clarified in the following definition: Dictionary (2011): *"the kind of action or activity proper to a person, thing, or institution; the purpose for which something is designed or exists; role"*. These definitions are similar in terms of the action and EU. They also concentrate on the suitability for the EU which should be considered when thinking about function implications. In terms of suitability, Answers (2011) defines functionality as *"The action for which a person or thing is particularly fitted or employed"*. This definition uses the word "fitted" to state that the design or element should be located or selected to be fit for EU need. Bryant et al (1998) claimed that the function can be divided into two categories, basic and secondary functions, which are different - as will now be explained. In terms of the basic function, it has been defined as *"The principle reason a product or service exists when operating in its normally prescribed manner"*. This definition includes several aspects for the fundamental function such as cannot change the design, or the product cannot be sold without a secondary function. In contrast, the secondary can be sold without satisfying the main function. If the main function is not optimised that can lead to loss of value of the product. On the other side, the secondary function is defined as *"the method to carry out the basic functions"*. Secondary function can be related to the aesthetics or ornamentation of a product, or anything extra.

In terms of functionality in software or the IT industry it is defined as *"The test affectivity characteristic describes the capability of the specified tests to fulfill a given test purpose"* (Zeiss et al., 2007, p.4). The purpose of the test is to verify if the function of the product is able to fulfil its intend purpose. Another definition that is attributed to functionality is *"a set of attributes that bear on the existence of a set of functions and their specified properties. The functions are those that satisfy stated or implied needs"* (ISO/IEC 9126, 1991, p.1). In this study, it is important to notice from this definition that functions have to satisfy both stated and implied EU wants. ISO/IEC 9126-1 (1991) defined functionality based on context of use as *"the capability of the software product to provide functions which meet stated and implied needs when the software is used under specified conditions"*. Bevan (1997, p.5) supports this view and stated that the end product should not be delivered without ensuring it has met its main purpose and functions.

The external and internal qualities of ISO 9126 have several ATTs; one of them is functionality, as presented in Table 3-1. Each of these ATTs covers many S-ATTs. Abran et al (2003) classified software ATTs to six main ATTs, which are summarised in Figure 3-6.

Chua and Dyson (2004) point out each S-ATT to ask various questions that need to be answered, which are shown in the following table (3-1).

Suitability	Can software perform the tasks required?
Accurateness	Is the result as expected?
Interoperability	Can the system interact with another system?
Security	Does the software prevent unauthorised access?

Table 3-1: Functionality Sub-Attributes (adapted from Chua and Dyson, 2004)

Each of the S-ATTs should be defined separately to understand what is meant from the software background, on the one hand. On the other hand, how they can be related to the PD is also important. The definitions of these terminologies are as follows:

Suitability (Test Coverage): "*Coverage constitutes a measure for test completeness and can be measured on different levels, e.g. the degree to which the test specification covers system requirements, system specification, or test purpose descriptions"* (Zeiss et al, 2007). The suitability in this definition is to what extent the function is covered by the requirements of the software.

Suitability: "*Attribute of software that relates to the presence and appropriateness of a set of functions for specified tasks"* (Lundberg et al, 2005). In this definition, there is a similarity with the previous one, especially in the appreciation of several functions together to meet specific tasks. Suitability in PD is the ability of the building elements' functions to fit together to maximise the advantages of the natural environment for optimum PLVT in order to satisfy EU needs.

Accurateness (Test Correctness): "*characteristic denotes the correctness of the test specification with respect to the system specification or the test purposes. Furthermore, a test specification is only correct when it always returns correct test verdicts and when it has reachable end states"* (Zeiss et al, 2007).

Accuracy: *"Attributes of software that bear on the provision of right or agreed results or effects"* (Lundberg et al, 2005). Accuracy is the degree of the quality that ensures the function is working well and applies it as expected. Accuracy in PD is to what extent the design element has achieved its function as well as to place it in the right place.

Security: the security "*covers issues such as included plain-text passwords that play a role when test specifications are made publicly available or are exchanged between development teams"* (Zeiss et al, 2007).

Security: *"Attributes of software that relate to its ability to prevent unauthorized access, whether accidental or deliberate, to programs and data"* (Lundberg et al., 2005). In PD this is about how to consider safety through the design of the space and provide elements which will not result in compromising the security of the building, as well as ensuring that the building is safe to use.

Interoperability: *"The ability of two or more systems or components to exchange information and to use the information that has been exchanged"* (Lundberg et al., 2005).

Interoperability: *"Attributes of software that relate to its ability to interact with specified systems"* (Lundberg et al, 2005). PD interoperability is how to interact the components or spaces with each other to optimise PLVT.

Compliance: *"Attributes of software that make the software adhere to application related standards or conventions or regulations in laws and similar prescriptions"* (Lundberg et al, 2005). The similar meaning in PD is how to apply PDS without any conflict with the regulations of the country.

Efficiency (Performance):

The second main ATT is efficiency, which plays a clear role in the software design. Based on it, this ATT will identify if the software functions perform what is expected. This reflects the relationship between the efficiency of the software and its function. Many authors have referred to this ATT. Bevan and Azuma (1997) are a good example. They referred to the efficiency of three S-ATTs that should be involved and met in the design, which are compliance, time behaviour and resource utilization. In brief, these S-ATTs are related to the software and whether it has the ability for quick responses; and also, if it uses the resources effectively in line with local regulations. External and internal qualities of ISO 9126 are referred to in these three S-ATTs by Abran et al (2003).

This main ATT is usually coupled with PD in terms of energy efficiency. The S-ATT terminologies need to be explained before starting to link them to PD. Some authors explain them as definitions and some of them as questions. The latest methods have been clarified by Chua and Dyson (2004), as illustrated in Table 3-2. Meeting these questions through design means the software design becomes efficient.

Time behaviour	How quickly does the system respond?
Resource utilization	Does the system utilize resources efficiently?

Table 3-2: Efficiency Sub-Attributes (adapted from Chua and Dyson, 2004)

Both of these terminologies will be defined separately to understand each one and how it is going to be used in or related to PD. This will help to understand them. S-ATTs will be illustrated in the following paragraphs. Lundberg et al (2005) defined each S-ATT as follows:

Time behaviour: *"Attributes of software that relate to response and processing times and on throughput rates in performing its function"*. This S-ATT refers in a simple sense to the time that the software will need to perform the functions. This gives a first indicator about the relationship between efficiency and performance.

Resource behaviour: *"Attributes of software that relate to the amount of resources used and the duration of such use in performing its function"*. This refers to the quantity of sources which should be used and the period which will determine completion of the function. This definition also gives the second indicators about the link of performance to efficiency. In addition to that, resource behaviour and time behaviour share in the time.

Compliance: *"Attributes of software that make the software adhere to application related standards or conventions or regulations in laws and similar prescriptions"*. As has been referred to in previous chapters, the efficiency should cope with the local regulations.

Also efficiency is defined as *"efficiency characteristic relates to the capability of a test specification to provide acceptable performance in terms of speed and resource usage"* (Zeiss et al., 2007, p.6). It is also defined as *"a set of attributes that bear on the relationship between the level of performance of the software and the amount of resources used, under stated conditions"* (ISO/IEC 9126, 1991, p.2). This also considers the resources used to maintain the performance of the design to high standards that respond to the user needs under various conditions. ISO/IEC 9126-1 (1991) defined it based on context of use as *"the capability of the software to provide the required performance, relative to the amount of resources used, under stated conditions"* (Bevan, 1997, p.5). All these definitions emphasize the relationship between resource consumption and the level of performance required from the product. This might suggest that the quality of the end product is directly attributed to the amount of resources used to develop it. What is not known is if this relationship is linear or otherwise. At a later stage, this research will aim to explore this problem through quantitative data.

Usability:

Usability is one of the main ATTs of the designing software. In terms of the functionality, usability is the third ATT as the researcher said the rest ATTs are related to functionality. There is a relationship between it and flexibility, where both of them are related to simplifying the design for the EU. Several authors have referred to the usability with regard to the software as well as they have determined its S-ATTs. Bevan and Azuma (1997) are a good instance when they referred to the usability when designing any software program, which should be covered by five S-ATTs. The importance of this characteristic is to design the software to be easier for the EU at the end of the day.

These are the main ATTs of external and internal qualities of software 9126; usability is one of them, which is mentioned by Abran et al (2003).

The main challenge is how to link them to PD; the easiest way for that is to understand each term separately and to use the method that Chua and Dyson (2004) have shown where they summarise each term as a question which should be met in order for software design to be usable, as is illustrated in the following table (3-3).

Understandability	Does the user comprehend how to use the system easily?
Learnability	Can the user learn to use the system easily?
Operability	Can the user use the system without much effort?
Attractiveness	Does the interface look good?
Compliance	Does the software comply with laws or regulations?

Table 3-3: Usability Sub-Attributes (adapted from Chua and Dyson, 2004)

In the following part, the definition of each term will be explained before being related to PBD in order to understand their main functions and the differences between them. This will be discussed in the following paragraphs. Lundberg et al (2005) defined each S-ATT as follows:

Understandability: *"Attributes of software that relate to the users' effort for recognizing the logical concept and its applicability"*. This illustrates to what extent the software should be easy for the EU to understand and this will be through simplifying the concept of software.

Learnability: *"Attributes of software that relate to the users' effort for learning its application (for example, operation control, input, output)"*. This shows how easy it is to learn the software process - its contribution and production.

Operability: *"Attributes of software that relate to the users effort for operation and operation control"*. This reflects the ability of software to be controlled by the EU in a simple way.

Compliance: *"Attributes of software that make the software adhere to application related standards or conventions or regulations in laws and similar prescriptions"*. This applies if the ATT is coping with the regulations without any conflicts.

Attractiveness: Lincke and Lowe (2007) define attractiveness as a *"sub-characteristic allows to draw conclusions about how attractive software is to the user"*. The software should be attractive to the EU, which could be in many ways such as colour or appearance.

Usability: it is defined as *“The usability attributes characterise the ease to actually instantiate or execute a test specification”* (Zeiss et al., 2007, p.5). This is concerned with how to consider some ATTs in the design of the product that might lead to the ease of use. Another definition is reported as *“a set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users”* (ISO/IEC 9126, 1991, p.2). The ATTs in this definition relate to the EU assessment of whether the product or software is usable or not. ISO/IEC 9126-1 (1991) defined usability based on context of use as *“the capability of the software to be understood, learned,* *used and liked by the user, when used under specified conditions"*. The last definition clearly indicates that EUs are the pivotal centre around which the product is designed and conceived.

Portability (Flexibility):

Flexibility, which is called portability in the software, is the third main ATT of the software. This ATT is the second ATT which will be under the umbrella of functionality. Bevan and Azuma (1997) referred to the flexibility when the design of any software programme could be covered by five S-ATTs. These S-ATTs should be considered together when the designer is keeping in mind the portability of the software. The portability (flexibility) is one of the main ATTs of external and internal qualities of software 9126 as well. The portability (flexibility) is the third one mentioned by Abran et al (2003).

The differences between the classifications above are the word conformance or compliance. These differences will be clarified through the discussion of these terminologies in the following paragraphs. Chua and Dyson (2004) explained each S-ATT as questions which need to be answered when designing software for portability, as shown in the following table (3-4).

Adaptability	Can the software be moved to other environments?
Installability	Can the software be installed easily?
Conformance	Does the software comply with portability standards?
Replaceability	Can the software easily replace other software?
Coexistence	Does the software co-exist with other software at the same time sharing the common environment recourses? [added by the researcher]

Table 3-4: Flexibility Sub-Attributes (adapted from Chua and Dyson, 2004)

The following part will explain the definition of each term before relating them to PBD to understand the differences and the main function of them. Lundberg et al (2005) defined each of S-ATTs as follows:

Adaptability: *"Attributes of software that relate to on the opportunity for its adaptation to different specified environments without applying other actions or means than those provided for this purpose for the software considered"*. Also, ISO/IEC 9126-1 (1991, as cited by Lundberg et al, 2005) defines adaptability as follows: *"The capability of the software product to be adapted for different specified environments without applying actions or means other than those provided for this purpose for the software considered"*. Both definitions are similar to each other but the first one refers to ATTs and the second one refers to the capability of the software, which could be similar in PD as that to design PB that have enough elements and aspects for specified environments.

Installability: *"Attributes of software that relate to the effort needed to install the software in a specified environment"*. Also, ISO/IEC 9126-1 (1991, as cited by Lundberg et al, 2005) defines installability as follows: *"The capability of the software product to be installed in a specified environment"*. The latter definition refers to the capability, unlike the first, which refers to the characteristics of the software where it demands an effort to install it in a specific environment. In PD, it is important to consider the flexibility of the element to be installed in a specified environment.

Replaceability: *"Attributes of software that relate to the opportunity and effort of using it in the place of specified other software in the environment of that software".* Also, ISO/IEC 9126-1 (1991) defined replacability as cited by (Lundberg et al, 2005) as follows: *"The capability of the software product to be used in place of another specified software product for the same purpose in the same environment".* This gives a clear indication about the capability of the software to fit with other software or with its environment. In PD, this could be in using an element or space aspect that could be changed with a change in the environment.

Compliance: Lundberg et al (2005) define it as*:"Attributes of software that make the software adhere to application related standards or conventions or regulations in laws and similar prescriptions".*

Conformance: *"Attributes of software that make the software adhere to standards or conventions relating to portability".* Both these terminologies are related to how the software is flexible in a way that copes with the regulations of law. This has been mentioned in the previous main ATTs' functionality and maintainability, when it has been referred to as ensuring that the PDS comply with the local laws.

Coexistence is defined by ISO/IEC 9126-1 (1991 as cited by Lundberg et al, 2005) as follows: *"The capability of the software product to co-exist with other independent software in a common environment sharing common resources".* This is similar in one way or another to the interoperability which has been referred to in functionality in terms of two elements or two strategies. Hence, in PD it refers to how capable the element is to work with other elements in the same circumstances.

Portability is defined as *"Portability in the context of test specification does only play a very limited role since test specifications are not yet instantiated* (Zeiss et al., 2007, p.6). It is also defined as *"a set of attributes that bear on the ability of software to be transferred from one environment to another"* (ISO/IEC 9126, 1991, p.2). This reflects the ability of programs to change their features or environment. ISO/IEC 9126-1 (1991) defined it based on the context of use as *"the capability of software to be transferred from one environment to another".* The consensus here is that the features of a designed product must be easy to transfer to different conditions of use. The portability is important from the point of view that if the product is unable to adapt to a new environment then it become obsolete and all the capital, both financial and EU resources, spent to develop the product will be wasted.

In terms of conformance in the software program some factors have been identified which could affect portability. These factors should be taken into account when designing the software to achieve standardisation with portability, such as local regulations. Brown (1977) classified seven factors that could affect portability; all of these factors are based on whether it can be determined if the software has portability or not. Brown also stated that that connecting flexibility with standardisation can enhance the software to have a great benefit. In addition, the tools or means could be easy to achieve. The factors that could affect portability are (1) the nature of the application and in particular its inherent degree of machine dependence, (2) computer size and structure, (3) the program quality, (4) general programmed methodology, (5) difference between tools such as linguistics, (6) concern with the organisation policy and structure, (7) U imposes standards, (8) how to satisfy commercial interest.

Reliability:

One of the main ATTs of the software is reliability. It is the fifth ATT when designing software. There is a clear relationship between the functionality and the design, as any design cannot perform its function if it is not reliable. This ATT and its classification have been agreed by several authors. Bevan and Azuma (1997) referred to the need to consider reliability when designing any software. The importance of this characteristic is to design the software to be reliable when faced with various changes. There are many ATTs of external and internal qualities of software 9126; reliability is one of them, as mentioned by Abran et al (2003).

The relationship between PD and these terminologies oncerning reliability is a clear challenge. For this reason, the need to analyse and understand them from a software background is a clear demand. One of the methods is what Chua and Dyson (2004) clarified; they formulated each terminology as a question in a simple and concise way. Meeting these questions in any software means that the software is reliable.

Fault tolerance	Is the software capable of handling errors?
Recoverability	Can the software resume working and restore lost data after failure?

Table 3-5: Reliability Sub-Attributess (adapted from Chua and Dyson, 2004)

Each one of these terminologies will now be explained as a definition before being related to PD. This will give a clear vision about the various dimensions for all of them, which will be discussed in the following paragraphs. Lundberg et al (2005) defined each S-ATT as follows:

Maturity: *"Attributes of software that relate to the frequency of failure by faults in the software"*. This in one way or another relates to the quality which reduces the possibility of malfunction of the software.

Fault tolerance: *"Attributes of software that relate to its ability to maintain a specified level of performance in cases of software faults or of infringement of its specified interface"*. This reflects to what extent the software can be adapted without any dysfunctions.

Recoverability: *"Attributes of software that relate to the capability to re-establish its level of performance and recover the data directly affected in case of a failure and on the time and effort needed for it"*. This reflects the ability of the software to restore its functions when any malfunctions such as loss of data happen.

There are also several definitions of reliability, each of which is concerned with the ability of the building to be sustained through changes. One of the definitions, by Blank (2004), is: *"The reliability of a process, product, or system is the probability that it will perform as specified, under the specified conditions, for the specified period of time*". This definition considers the changeability of the surrounding circumstances and how the system can respond to the changeability in the specific time.

Also, this refers to performance of the system under specified conditions and over a specified period of time. Another definition is that *"Reliability is the probability of a device performing its purpose adequately for the period of time intended under the operation conditions encountered"* (Bazovsky, 2004). This is about the ability of the product to face several conditions for a specific period. Louis (2005) defined reliability as *"the probability that an item will perform a required function under stated conditions for a stated period of time"*; and he also analysed the definition in four main classifications as follows: (A) probability; (B) function of time; (C) function of defined condition; (D) function of definition failure. The reliability of the product is the probability that the product (system) will perform its intended function for a specified time period when operating under normal environmental conditions (Blischke & Murthy, 2000). These definitions are centred on several points as follows: (1) performance as it is specified; (2) performance in predicting changeability; (3) performance in function of time; (4) performance under specific conditions; and (5) avoidance of function failure. Reliability can also be defined from several perspectives, as Barringer (1998) claimed. The first definition was based on a general sense as follows: *"As a general sense, reliability is the ability of an item to perform a required function under stated conditions for a stated period of time"*. As a characteristic, it is defined as follows: "*As a characteristic, reliability denotes the probability of success or the success ratio"*. From the quality perspective it is defined thus: *"reliability exists by design as an objective or a requirement of a product from its inception to the end of its working life"*. The third perspective is based on a probabilistic statement as follows: *"reliability is concerned with the probability of future events based on past observations"*. Reliability as a basic concept is characterised as follows: *"durable and high probability of failure-free performance under stated conditions including all item life units, not just mission time and all failure with the item, not just mission critical failures at the time level of assembly"*. In general, the concept of reliability is classified as *"a special development of engineering industries for the collective measures of quality that reflect the effect of time in storage or time in use of a product. The concept is distinct from measures that show the state of the product at time of delivery"*. Finally, from the point of view of a business concept, reliability is concerned with *"a balanced integration of strategies for procurement, installation and start-up, equipment/process operations, maintenance, and reliability which avoid failures and maintenance interventions by focusing on the long term cost of ownership in financial terms to avoid waste and optimise plant availability"*. ABCB (2006) defined it as *"the capability of a building or its parts to perform a function over a specified period of time"*. Durability is: *"the ability of a building or any of its components to perform its required functions over an intended period of time"* (PERD, 1997, p3).

Reliability is defined as *"The reliability characteristic describes the capability of a test specification to maintain a specific level of performance under different conditions"* (Zeiss et al., 2007, p.5). Other definitions exist, such as *"a set of attributes that bear on the capability of software to maintain its level of performance under stated conditions for a stated period of time"* (ISO/IEC 9126, 1991, p.2) and ISO/IEC 9126-1 (1991): *"the capability of the software to maintain its level of performance* *when used under specified conditions"* (as cited in Bevan, 1997, p.5). All definitions agree that the product should be able to perform under the stated conditions.

Maintainability:

The functionality forms the main umbrella for the rest of the main ATTs which are maintainability, reliability, usability, flexibility and reliability. Bevan and Azuma (1997) suggested that the maintainability when designing any software program could be covered by four S-ATTs. These S-ATTs should be considered together when the designer is thinking about the technology needed to maintain the software. The second main ATT of the external and internal qualities of software 9126 is Maintainability, as mentioned by Abran et al (2003). Chua and Dyson (2004) explained each S-ATT as a question which needs to be answered, as shown in the following table (4-27).

Analyzability	Can faults be easily diagnosed?
Changeability	Can the software be easily modified?
Stability	Can the software continue functioning if changes are made?
Testability	Can the software be tested easily?

Table 3-6: Maintainability Sub-Attributes (adapted from Chua and Dyson, 2004)

To clarify these terminologies, each one should be understood separately; therefore, they will now be defined one by one. In addition, the possibilities to match them to PBD will also be discussed.

Lundberg et al (2005) defined each of the S-ATTs as follows:

Analysability *"Attributes of software that relate to the effort needed for diagnosis of deficiencies or causes of failures, or for identification of parts to be modified"*. This definition refers to what extent the personnel need to identify the dysfunctional element or space as well as the causes of it.

Changeability *"Attributes of software that relate to the effort needed for modification, fault removal or for environmental change"*. In this definition, changeability could relate to time and simplicity of design to repair the mistake easily and so remove it.

Stability *"Attributes of software that relate to the risk of unexpected effect of modifications"*. How the design can be stable when any risk appears during the modification of elements or the space.

Testability *"Attributes of software that relate to the effort needed for validating the modified software"*. This is the last stage of maintainability which comes after modification to check if the dysfunction is fixed or not.

Maintainability is defined as *"Maintainability of test specifications is important when test developers are faced with changing or expanding a test specification"* (Zeiss et al., 2007, p.6). And it is also defined as "*a set of attributes that bear on the effort needed to make specified Modifications"* (ISO/IEC 9126, 1991, p.2). This reflects the level of effort which is needed to maintain the software through its life cycle. It is clearly the maintenance effort and cost of developers that are the main drivers here. ISO/IEC 9126-1 (1991) defined it as *"the capability of the software to be modified. Modifications may include corrections, improvements or adaptation of the software to changes in environment, and in requirements and functional specifications"* (Bevan, 1997, p.5). This last definition requires that the software must be able to be changed or modified easily when there is a correction or a need for imperative improvement to meet EU needs.

Maintainability or ease of maintenance is one of the most important issues which should be considered during the PD process. This will not conflict with the PDF. It will enhance the function in case any dysfunction happens, which can then be quickly and easily fixed. For this reason, there is a need to understand the definition of ease of maintain before starting to explain how this can be considered in the PD from various angles. In fact, there are various definitions which have been referred to by several authors. Some of them share some aspects. According to BIS (1993, as cited by Das et al, 2010, p.1043), maintainability is defined as *"the ability of an item, under conditions of use, to be retained in or restored to a state in which it can perform its required functions, when maintenance is performed under stated conditions and using prescribed procedures and resources"*. Maintainability is paired with other ATTs and this is obvious in the definition where it has referred to the function and performance at the same time. Restoring the function of the element or design space means guaranteeing the longevity of the function. This is achieved through relating elements with expected defects to future maintenance. In addition to that, another definition looks to ease of maintenance for several routes; some of them are the same as or similar to the previous definition routes.

Dunston et al. (1999, p.56*)* defined maintainability as *"the design characteristics which incorporate function, accessibility, reliability and ease of servicing and repair into all active and passive system components that maximises costs, and maximises benefits of the expected life cycle of a facility".* This states that the design should be easy to access; more reliable in order to reduce the cost of maintenance, and that the building and elements should be more durable. This matches the previous definition with the concept of considering expected future maintenance, which reflects the importance of simplifying the design to avoid using complex or low quality materials. Accessibility of the building could be considered as access to the element or space. This marks the differences between this definition and the other one. Its importance will be clarified in the discussion of PDM.

Hasselbring (2006) defined maintainability as *"The ability to undergo repairs and modifications"*. There is a definition that maintainability *"encompasses corrective, preventive as well as perfective or adaptive maintenance"*. It does not immediately refer to the operation of the system, but to its design. Both definitions refer to the design of maintenance, and to what extent design can help in the maintenance of the building.

Stephen et al. (2011) defined maintainability as *"The relative ease and economy of time and resources with which an item can be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair".* This definition looks to the simplicity of mainataiability.

Maintainability has also been referred to as *"A characteristic of design and installation, expressed as the probability that an item will be retained or restored to a specified condition within a given pe-*

riod of time, when maintenance is performed in accordance with prescribed procedures and resources”. The last two definitions look at usability and ease of maintenance together.

From these definitions, it could be concluded that ease of maintenance is centred on three S-ATTs. First of all, standardisation refers to applying the design and using the elements based on standardisation. Secondly, refers to the materials and the importance of longevity and quality. Finally, accessibility and cleaning refer to ease of maintenance and access to the defective area.

Issues learned from the literature	Argumentations	Research gaps	Research Questions
Is the U of the building the occupant only?	As per the literature review discussed in this chapter, the U may not be the occupant.	There is a need to investigate which types of U have to be considered during the design process.	What is the suitable classification for U?
Is there a method that bridges the gap between design and U needs?	As per the literature review discussed in this chapter, there are different methods that consider U needs.	There is a need to investigate which method could have a clear impact on building design.	What is the suitable method that can help the designer to meet U needs?
What to do in case there is no method?	As per the literature review discussed in this chapter, the method has been applied in different fields.	There is a need to investigate the possibility to use the method in building design	What is the suitable way to transfer the method to building design?
Is there a clear classification for PDS; what are the dimensions of PD?	As per the literature review discussed in this chapter, the strategies could be classified in different ways.	There is a need to classify the PDS to be the starting point of the conceptual model.	What are the dimensions of PD?
Are there design ATTs that could help the designer to meet U needs?	As per the literature review discussed in this chapter, the ATTs could be classified in different ways.	There is a need to investigate the suitable classification for design ATTs.	-What are the PDHAs that have to be considered? -How many ATTs need to be involved in the proposed model?
Are there design S-ATTs that could help the designer to meet U needs.	As per the literature review discussed in this chapter, the S-ATTs could be classified in different ways.	There is a need to investigate the suitable classification for S-ATTs.	-What are the PD S-ATTs that have to be involved in each ATT? -How many S-ATTs need to be involved in the proposed model?
Is there a design process that the designer can follow to meet U needs?	As per the literature review discussed in this chapter, the design process could be available.	There is a need to investigate the design process that considers U needs in different ATTs.	What are the suitable design processes that could help the designer to meet U needs?
How can the interaction between Us needs and PDS be created?	As per the literature review discussed in this chapter, the interaction could be made through creating model based on another approach.	There is a need to investigate which EUFs would have an effect on design PD and to model their interaction accurately.	How can the relationship between PD and U needs be modelled?

Table 3-7: The issues learned from the literature

3.4 Summary of this Chapter

From what has been reviewed in the previous sections, ISO 13407 deals with design processes, and 9126 which deals with design attributes have inspired the researcher to develop a UCPBD model. The two ISO standards, coupled with building design concepts, which motivates the researcher to adopt them in developing the UCPBD conceptual model. These standards have also inspired the researcher to extract and define the ATTs of UCPBD theory. The following chapter will show the framework of UCPBD which includes ATTs , S-ATTs and their EUFs.

Chapter Four: Passive Design Human Attributes

4.1 Introduction:

The designer should select the building design elements based on their passive function requirements as well as on EU needs. The PDF is the first most important design step. It could be described as an umbrella under which all other ATTs reside. The rest of the ATTs are directly correlated or attributed to the functionality. In this way, the three dimensions of PLVT are taken into consideration by the designer. The architect should have a good knowledge of how to specify and select PDS that are not in conflict with each other. They should also consider the interoperability between all strategic functions. Finally, each main ATT should capture EU needs through UCD processes. This research has identified six main ATTs. The S-ATTs for each ATT are specified based on ISO 9126. Figure 4:1 shows the S-ATTs for each main ATT of the UCPBD.

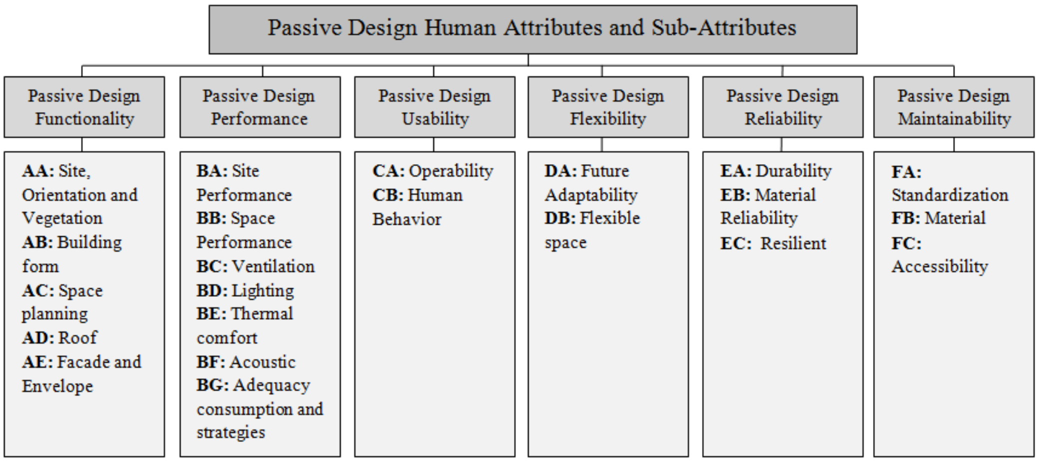


Figure 4:1: UCPBD ATTs and S-ATTs

PDHAs are defined as: factors that capture the needs, wants and limitations of EUs in relation to functionality, performance, maintainability, reliability, usability and flexibility. These ATTs will be used to aid designers to integrate PD issues and EU needs into the design process. This research replaced the efficiency and portability criteria by performance and flexibility respectively. The term performance was selected instead of efficiency to assess PD effectiveness. Furthermore, the term portability was replaced by flexibility because the latter is in line with current architectural practices. The number of S-ATTs for all main ATTs is 22 as illustrated in Figure 4:1. These ATTs are constituted from 132 EUFs or S-ATTs. The 132 EUFs included in the proposed theoretical model of this research will be explained one by one in the following sections.

4.2 Passive Design Functionality (PDF)

PDS are considered to be the foundation of the building design; without them PD will not function properly and it will not fulfil its intended purpose. The function of an ATT is focused on providing the utility that fulfils EU needs. This will be achieved through optimising the details and elements which work together cohesively. This will avoid any malfunction between the PDS. For this reason, the designer should consider the various functions between the design elements and how to create harmony between them without any conflicts, which of course will lead to providing PDF as the EU requires. As a result, PDF is defined in this research as: a set of design determinants that relate to the existence of a set of PD functions (i.e. Ventilation, Lighting and Heating) that fulfil user needs .The designer should integrate these strategies into the design in a way that enhances EU needs and their comfort. The functionality attributed is directly correlated with PDP measures. There are five S-ATTs that measure functionality, namely: site, orientation and vegetation, building form, space planning, roof and façade. Each of them has various EUFs which can enhance the PDF. They will be reviewed one by one in the following sections.

4.2.1 Site, Orientation and Vegetation

As the surrounding physical elements can have positive or negative impacts on the site, as well as on the landscape, they should be considered and spread in a way that promotes PDS. Panagopoulos (2008) claimed that one of the main conditions which makes the space function successful or not is microclimate, as presented in Figure 4:2. To be accurate, the landscape should be considered as a part of PD. This can have a clear impact. This can be achieved through providing landscape such as trees which can affect the amount of sunlight accessing the building. The architect should consider spreading the landscape over three sides [west, south and east] to provide shading in the summer to protect the building from heating gains. The tree spread should be suitable in both summer and winter (United States Department of Energy, 2000). This is in terms of the seasons. However, at a daily level the trees should block the low sun during the day to reduce the cooling load. This demands the provision of suitable trees in terms of the size and location in a way that enhances functions. The trees can affect the microclimate of the building through affecting day lighting performance. For this reason, it has been confirmed that there is a need to analyse the microclimate around the space and the residential area (Hongbinget al, 2010). Panagopoulos (2008) referred to the importance of considering plants and trees, as both can affect and help to provide PH to the space as well as save energy. The trees can have two important roles protection from solar and providing shading. The evaporated trees help to decrease the urban temperature. 80% of buildings in hot and humid climates are affected by shade from trees which cools the building (Shashua et al, 2000). Of course, this will only happen if the designers consider the tree locations and numbers. This will lead to an increase in the efficiency of indoor air quality and ensure that trees are not obstacles or burdens on the site. In some cases, their distribution can lead to improving the view of the building. Shashua et al (2000) and Hongbinget et al (2010) claim that it is important to have an

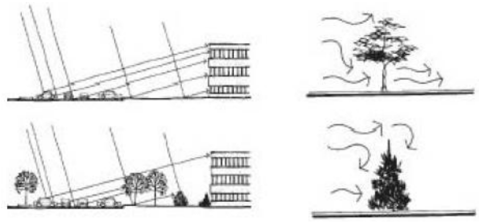


Figure 4:2: The effect of the landscape on sun collection (Panagopoulos, 2008)

accurate analysis of the area surrounding the space in terms of landscape, whether the site has already been landscaped or not.

The relationship between the indoors and the outdoors can have a positive impact on the PDF. It is confirmed that the building can be protected from the hot sun by self shading (Nikolopoulou et al, 2001). The landscape design can provide PH through optimising the quantity of wind or sunshine or shading which of course mitigates the temperature.

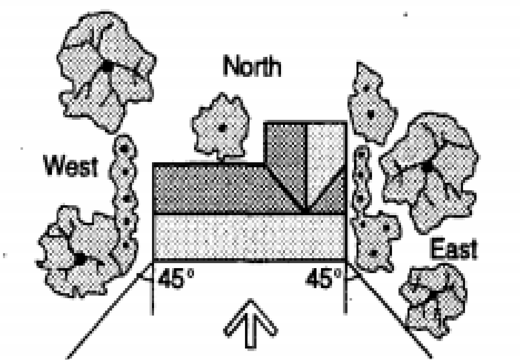


Figure 4:3: Distribution of trees (Passive Solar Industries Council, National Renewable Energy Laboratory, and Charles Eley Associates, 1994)

Building Information Modelling (BIM) (2011) confirmed the importance of accurately positioning plants to avoid obstructing the air flow; at the same time, this can control the air flow. Providing landscaping can create interoperability between the EU and the outside and enhance their interior indoor comfort in various ways, as Ahsan (2009) claimed. It is said that using the landscape can lead to reductions in noise and pollution, reduce energy consumption, mitigate the “temperature degree and relative humidity”, and finally enhance the EU psychologically (Ahsan, 2009). This means to accurately landscape plants and trees to be suitable for the EU. The interoperability between the landscape and EU which has been referred to can lead to optimising the PDF and guaranteeing that it is provided as it is required. Providing landscaping can lead to providing interior comfort.

Lechner (2009) identified that the suitable place for trees in the majority of countries is on the directions north, east and west as shown in Figure 4:3. This is in cases where trees are available, but if they are not, they can be replaced by other methods such as bushes, trellis and vertical fins; these methods can be effective on east or west aspects. These methods will affect PV by controlling the wind direction as well as providing shade. Installed fountains or water pools can create cooling air. A vegetative roof is one of the approaches that can cool the air breezes. This approach is mainly used in hot climates. The role of trees is not only to prevent sun radiation but also reflection of some rays coming from surrounding areas such as building surfaces and the sky (Oke, 1989). For this reason, there are many limitations that can affect the PL such as the distance between the building and the trees, the size of the trees, the height of trees and so on. The availability of trees at the urban level can affect air temperature at different levels from the street trees to the larger boundary. The level of the effect depends on the extent of the interoperability between trees and other urban environment elements. At the building level, the tree should accurately follow the hierarchy of building level, site level and urban level. The distance between the trees on a street can have an impact on the

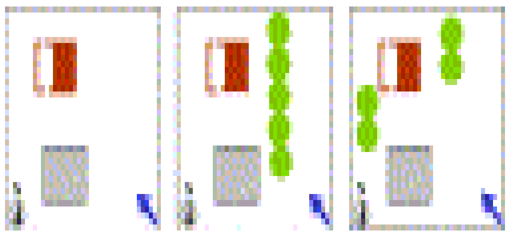


Figure 4:4: The various positions of trees in the case study (Akashi et al, 2006)

street as well as if there are other trees in the garden of the building. Finally, with regard to the highest trees and buildings, each of these situations should be considered separately and accurately in order to be located as pillars for optimum PV and not as obstacles to it.

Figure 4:5: Roof Garden (Punggol Roof Garden, 2003).

Akashi et al (2006) evaluated one building to see the effect of landscape (tree) on interior cooling of the building (natural ventilation). Three situations were assumed to measure it. The authors assumed that the building had no surrounding trees in the first case. In the second case, the trees were around the building in two positions, as shown in Figure 4:4. One of the findings was that the position of trees around the building affects the cooling load. For this reason, considering the design of the microclimate around the building is essential to gain the benefit of PV (Akashi et al, 2006). This gives another indicator for designers, which is to accurately assess the circumstances of the site in terms of landscape during the design process. As has been mentioned above, the distribution of landscape strategies should be optimised. In the layout of the building, using gardens can affect the performance of cooling inside the building. Hence, cool and shady places are provided in the summer time. Many landscape factors such as trees, flowerbeds, vine trellises, and soft ground surfaces can be interoperable with the climate and human factors to create comfort both inside and outside the buildings (Brown and Gillespie, 1995).

Figure 4:6: ACROS Fukuoka: The serene green roof of Japan (Kumar, 2008).

In both cold and hot climates, the green roof has rapidly become a consideration in building design. In contrast, in a cold climate, the green roof's purpose is to store and filter the rain water (Panagopoulos, 2008).The green roof has been installed in different countries around the world as a solution for PH and PV as well as for aesthetic views, as shown in Figure 4:5. ARUP (2012) referred to other positions for landscapes, such as providing landscaping on the courtyards and roof. For the latter, the best example is ACROS Fukuoka in Japan as shown in Figure 4:6 - the serene green roof of Japan. Each of them can play a clear role in PD, when the green elements are accurately positioned. This is interoperability between the EU of space and the landscape, whether on the outside or the inside of the building, and several authors have indicated this relationship. Hartig (1991) confirmed that a green roof can provide psychological benefits for EUs at an urban level. It also helps to offer visual comfort and reduce EU stress. However, when the designer offers interoperability between the green area and the space, this will make the space more attractive, and might enhance EU productivity. Brown et al (1995) declared that there are different reasons to provide landscapes in the area and space. One of these reasons is to create thermal comfort for EUs. It is also claimed that achievement of thermal comfort for the EU at the landscape level can be when the energy lost is equal or nearly equal to that which is received. For this purpose, thermal comfort is a complex process and it cannot be controlled easily. For instance, the heating sources in the space are different, such as EU, the outside and the interior space. The main challenge when adopting landscaping is how to make a balance between each of them where neither surpasses the other.

The orientation of the building should also be optimised to the prevailing wind and solar access, which of course should be based on the previous investigation and site analysis. The orientation of buildings is indicated by several authors. The United States Department of Energy (2000), BIM (2011) and the Ministry for the Environment (2008) said that the building placement should be accurate for maximising solar access and ventilation strategies. It is added that the changes in the seasons should also be considered, such as in the summer the solar access should be minimised, and maximised in the winter. For this reason, the building location and features should be compliant with the changing seasons.

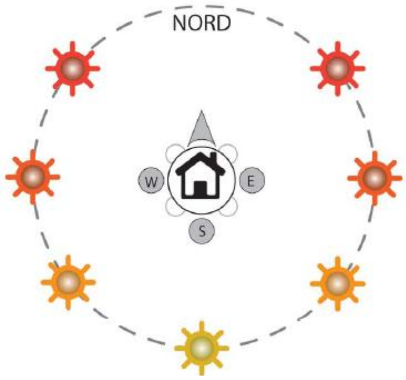


Figure 4:7: Various site orientations (Crobu, 2010)

Optimum orientation can be through orientating the building's long axis to the south to benefit from solar access and the prevailing wind will be from the west. Jefferson (1789, p.113) defined orientation as *"an action step permitting passive design features and non-mechanical measures to conserve energy, utilize solar energy for thermal gain, and direct prevailing winds for natural ventilation and cooling"*. This definition covers the main function of orientation and the similarity with the aim of PV. The location and orientation of the building should be considered because any direction has its level of temperature, as Crobu (2010) classified as follows and as shown in Figure 4:7. The south facing is the most suitable position and best orientation; the east is possibly cold in winter and pleasant in summer; the west has high temperatures during summer; and finally the north has the coldest wind during winter.

Several authors confirmed that the south orientation is one of the essential indicators of which to take advantage if it is possible. Fernandez-Gonzalez (2007) considered that the largest elevations should be to the north and south to reduce the thermal transmittance and to increase optimum solar collection. Norton and Christensen (2006) discussed the Habitat for Humanity home near Denver, Colorado: this case study has shown the need to consider orientation to the south, and they showed the long façade was to the south. This is to benefit from the natural environment. The size of opening is increased on the south more than on other façades, as will be shown in Figure 4:8.


Figure 4:8: South facade (Norton and Christensen, 2006, p.2 and 4)

Orientation to the south at 30 degrees has been indicated by many authors such as the United States Department of Energy (2000) and Badescu et al (2011) to be the suitable degree. The latter indicated the first PD in Romania which was oriented to the south at a 30 degree angle. Different places were grouped to the south orientation. The south façade was the longest as well as having the largest number of windows, as shown in Figure 4:9.

Figure 4:9: Perspective and south elevation of AMVIC office building –Romania (Badescu et al, 2011, p.143 and148)

It has been confirmed through analysis that the highest achievement of day lighting in the orientation of school classes is when the large axis is in both north and south orientations and the exposure is both west and east (Kruger and Dorigo, 2008). The south and north are more preferable than east or west because the sun is very low in the east or west, for that reason a south orientation is preferred (Baker and Koen, 2002). This demands accuracy in the site analysis. Matthias and Amato (2009) claimed that each building has different façades in different orientations. The optimum orientation in various climates can be north and south orientation which means the long façade will be on those sides with minimal parts of the building facing to east and west. This case will not always be in the warm climates. The best prevailing wind orientation is to north and south which means the prevailing winds will be from those sides. Garcia-Hansen et al (2002) in their case studies considered that buildings that do not face north are not desirable, as well as considering the obstacles of the day lighting on the northerly façade and the poor design in terms of PDS. The case studies were in Argentina. The location of the building can determine the best orientation. It has been confirmed by Li et al (2006) in Hong Kung that the suitable way to face is to south and south-east because the amount of day lighting is more than on other faces, which means that facing south and south-east is more favourable for both designers and people using the building. This indicator explains the extent of the interoperability between the PL and EU and to what extent they should be interacted together.

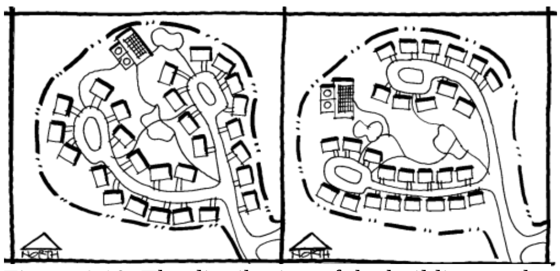


Figure 4:10: The distribution of the building on the site (US DOE) (2001)

Ekici and Aksoy (2008) assumed three rooms with different façade areas to simulate to what extent orientation can affect heating and cooling areas. The result was façades 1/1 and 1/2 achieved the most gain in heating during the period of the study. In contrast, the large faces of both north and south façades were the reason behind the gain of sunshine.

There is interoperability between the orientation of buildings and the site where the placements of buildings can benefit from natural environmental effects such as sun and ventilation. This will be by distributing the buildings on the site (US DOE, 2001). One of them will benefit from PV by different orientation measures to the south and north. The distribution of the buildings on the site should be accurate in a way to ensure benefits from the solar energy and wind direction. Separate buildings on the site will increase the opportunity of benefits from the wind and other natural resources, as presented in Figure 4:10. This distribution could be part of compliance of the design to benefit from the environmental conditions. Jiang and Chen (2002) pointed out that the prevailing wind is from the north side and the northwest direction. The measurement was in the experimental period for a site located in the south of Japan. As stated above, the north direction received the prevailing wind; therefore, the largest and widest façades were to the north and south to gain the benefit of PV and PL.

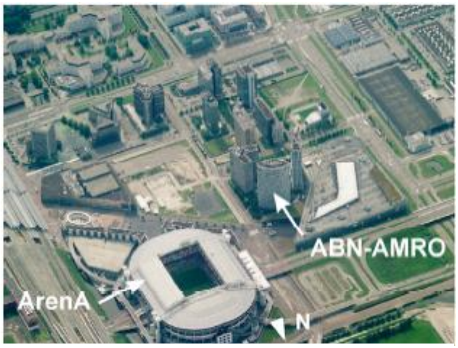


Figure 4:9: Impact of the surrounding buildings (Hoof and Blocken, 2009)

There are many limitations of PV that can affect optimisation of PDS functions such as the surrounding buildings; in some cases it may be an obstacle of optimising PDF. During studies of wind direction on sites, Hoof and Blocken (2009) said that the urban environment must be taken into account in order to accurately produce PDS. This was the result of analysing the effect of surrounding buildings which are affecting the wind direction. The case study was Amsterdam Stadium and its surrounding area, as shown in Figure 4:11. In this case study, the surrounding area contained high rise buildings, which can be obstacles to the wind direction. The designer should consider the current condition and expected condition of the surrounding area in order to obtain the benefits over a long period of time. This will be to create interoperability between the main construction site and the current surrounding buildings as well as any expected buildings. This is not the general case. In cases when the surrounding building is lower than the building which needs to be ventilated, there are numerous factors that can be considered such as the location of the building, or the part of the building which demands the ventilation, e.g., if it is at the same level or higher than them.

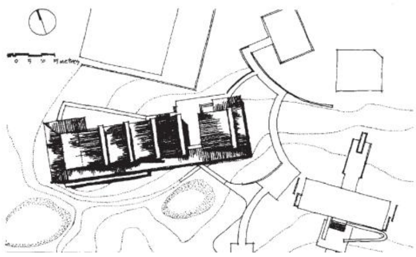


Figure 4:10: The site of the Design Faculty building at Newcastle University (Prasad and Fox, 1996).

In some cases, other factors on the site can affect the PV. For instance, air pollution and noise, especially if the buildings are located in high activity spaces like the centre of a city. However, buildings in suburban areas are preferred to houses in the city in terms of the neighbourhood being cleaner and less dense (Tantasavasdi et al, 2001). Lower density of housing or buildings leads to reduction of the air pollution due to less use of cars, on the one hand. On the other hand, the majority of buildings in suburban areas are separated, which is suitable for accurate application of PDS. The University of Newcastle's Design Faculty building is a good example. It was oriented to take advantage of PV and prevailing breezes as shown in Figure 4:12 (Prasad and Fox, 1996).

There is another function that should be considered when orientating the buildings, which is the outside view (BIM, 2011). This is to enhance the EU comfort. The challenge for the designer is how to provide and interact the view and the environmental conditions when orienting the building. Another challenge should be considered and sometimes could be restrictive, which is the infrastructure and local conditions. For this reason, the designer should adequately consider orientation and building location with the current conditions (Ministry for the Environment, 2008). Optimum orientation was traditionally considered. This can be seen clearly in traditional cities when they used wind catchers or other techniques from long a time ago (Department of Education, Northern Ireland (DENI) and corp creator, 1998). These strategies cannot work without the right orientation or investigation of the climate.

Figure 4:11: Natural and unnatural site obstacles (Crobu, 2010)

Site analysis is the first stage which the designer should consider in order to achieve the most suitable orientation and location. The accuracy of site analysis, to find out how the site would benefit from its natural environment, can help the designer to optimise the other design functions. This can be achieved through creating interoperability between three themes: site analysis, landscape, and orientation. The ideal interoperability between these themes can lead to maximising benefits from the natural environment such as solar access and prevailing wind. Both of them are the main feeders to the success or failure of PD applications.

Crobu (2010) determined several factors that can be an obstacle on a site, stating that optimising a site is not always possible, as shown in Figure 4:13. This can be due to physical surroundings, trees or topography. Sometimes providing trees in the south could be a barrier to solar access to the building which will create dysfunctionality between trees. This is in terms of PL; in terms of ventilation it could be create over-shading which will lead to reduce the heating of the space. For this reason, selecting the suitable place for trees can optimise the PLVT which of course will demand a clear analysis of the site to accurately assess its shading and solar access. This will depend on the density of trees and plants around the space .The topography sometimes could lead to overheating, such as when the topography slopes to the west, as it will receive more sunshine than the east, which will not be suitable. In this case, it could be expected that some solution to prevent overheating would be provided. Sometimes, the surrounding topography can be a barrier to PL or PV.

Jefferson (1789) points out that the building location on the site should be accurate in order to take advantage of breeze, topography, wind, sunlight or shade. Consideration of the surrounding buildings is one of the most essential factors. This is because the surrounding physical structures could be supportive to achieving PDF or an obstacle to it. The surrounding area's development can also affect the performance of PL. Capeluto (2003) pointed out that the performance of PL can be affected by the external pattern of the building. For this reason, orientation and PD is to benefit from PL. For this reason, factors in the urban environment like high rise buildings and density of the buildings can be barriers to the performance of PL. The size and width of a street can play an essential role in terms of providing PL or not. This is clearly reflected in the traditional city which is distinguished by narrow streets as well as by buildings being close to each other. The siting of the streets can play an important role by supplying PL to the low levels of a building, especially for buildings with multiple storeys. Capeluto (2003) states that the width of the street needs to be accurate, because it can provide the space with PL. This will be by spreading the angle of PL to provide sunshine to the lower floor. Belakehal et al (2004) confirmed that some urban designs can cut down sunlight, however, they illuminate the street, as shown in Figures 4:14 and 4:15. A neighbouring building can also affect PL through shading. For this purpose, it must be analysed in detail (Lam, 1997). This analysis is a clear sign of accuracy. PL is not at all harsh or unacceptable but sometimes the building area around can obstruct the efficiency and performance of a PL scheme (Li, 2007). Several authors referred to the interoperability between sites and surrounding area. BIM (2011), the Ministry for the Environment (2008) and Ahsan (2009) point out the need to mitigate the impacts of the surrounding physical buildings or topography on the site generally and building especially, such as over-shading and wind breaks. However, physical buildings or topography can sometimes be suited to shade the building which means providing optimum shading (Ahsan, 2009). For example, if the building is placed on the sloop site, the south side cannot benefit at all. In the case of the south façade facing the sunshine, this is an optimal orientation but if there are some obstacles to it such as mountain, high building or something else it will not be suitable. Even though some studies have found that the impact of geographical location is very low (Krarti et al, 2005), it is clear that geographical location is one of the factors that can help the designer to optimise PL and vice versa. This shows the interaction between the PDS and how can affect each other function. For example, there is no point to ptimise the building orientation when the the geographical location could not optimised the PL. For this reason, before thinking of building orientation or applying the design elements of PL, the site must be analysed to determine if there are obstacles that need to be considered with regard to suitability of site function. Then, consideration needs to be given to whether or not any obstacles are surmountable. In this case the orientation will be accurately based on the result of the site investigation. Hinkel et al (2003) classified site considerations to four factors which are physical

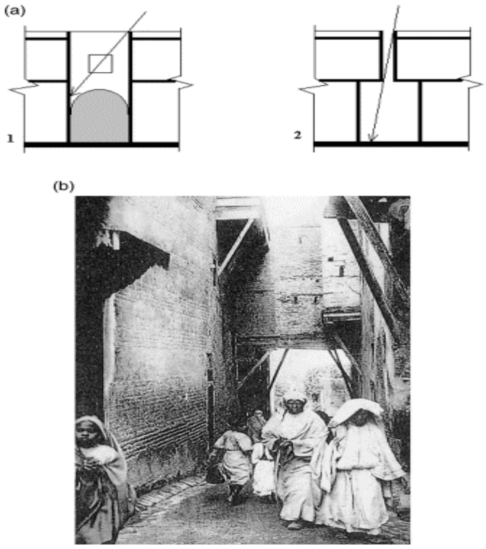


Figure 4:12: The density of the building (Belakehal et al, 2004)

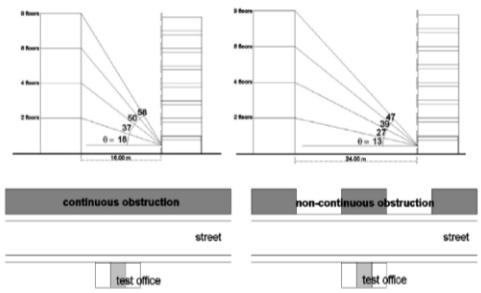


Figure 4:13: The width of the street and the affect of day lighting (Belakehal et al, 2004)

setting, urban morphology, energy use and temperature monitoring. Each of them is classified in terms of PLVT. This classification is acceptable to some extent but it is the difference between the factors which should be considered, as well as the physical factors and climate issues. Investigation of the site circumstances are a clear demand for optimisation of solar access and prevailing wind, as has been stated above. The topography and thermal heating are interoperable to some extent, as locating the building in the right place and benefiting from the changeable level of topography can help to enhance the thermal comfort. Earth sheltering is a good instance. Ip and Miller (2006) and (2009) referred to the case study which has been applied in Brighton, as shown in Figure 4:16. In terms of thermal comfort, the building can benefit from the earth rammed wall which acts as a heat store. This is a clear benefit from the topography and site circumstances. Its operation is that the earth will play the role of thermal mass to store the heat which is resulting from the earth wall and space. The earth shelter works as a thermal mass by using rammed earth as a heat conserver. The glass and mass is interoperable to capture sunshine. The heat is stored in the summer and warms the space in the winter. The earth shelter is a battery charger which can create a clear interoperability between it and the façade angle where it is inclined to be perpendicular to the winter sun gain at the lowest point in order to maximise the solar gain. This shows how to fit the building location to the site condition. The designer should ensure that the design is compliant in order to benefit from the site circumstance at different levels of form, angle of façade and distribution to cope with the topography.

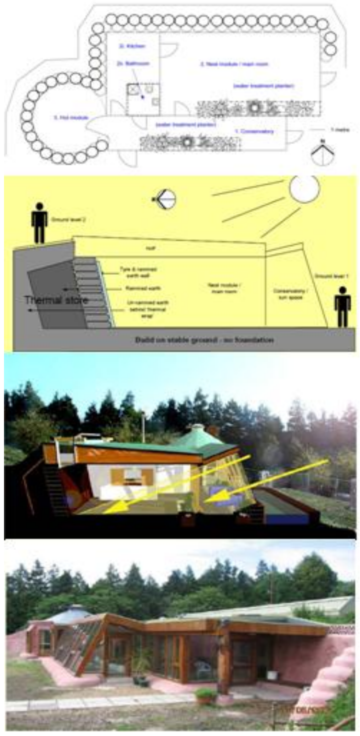


Figure 4:14: The Brighton Earth ship is located in Stammer Park (floor plan, section and perspective) (Ip and Miller, 2006 and 2009)

The United States Air Force (2011) has identified some aspects of the site which can affect the PDF. The aspects are shape and size of adjustable facilities and vegetation which could affect wind, solar, topography and ground cover. This is a clear indicator of the importance of the topography of the site and the shape of the building in which the land form plays a clear role.

This has been confirmed by the Ministry for the Environment (2008), which stated that analysis of the site conditions can lead to identification of the suitable wind strategy. This is not limited to ventilation strategy but can also be applied to the rest of the PDS (lighting and thermal comfort). The site investigation can be classified as the first stage which determines the success or failure of application of PDS, as this stage involves several functions such the topography and surrounding building. These can play a big role in the provision of shading and solar access as a positive rate and vice versa.

Code	End User factors	References
AA1	Use vegetation for optimum lighting, ven-	Panagopoulos (2008), United States Department of

	tilation and thermal comfort	Energy (2000), Hongbinget et al (2010), Shashua et al (2000), Nikolopoulou et al (2001), BIM (2011), Ahsan (2009), Lechner (2009), Oke (1989), Akashi et al (2006), Brown and Gillespie (1995), Hartig (1991), Brown et al (1995)
AA2	Orient the building for optimum lighting, ventilation and thermal comfort	United States Department of Energy (2000), BIM (2011) Ministry for the Environment (2008), Jefferson (1789, p.113), Crobu (2010), Fernandez-Gonzalez (2007), Norton and Christensen (2006), United States Department of Energy (2000), Badescu et al (2011), Kruger and Dorigo (2008), Baker and Koen (2002), Garcia-Hansen et al (2002), Li et al (2006), Ekici and Aksoy (2008), US DOE (2001), Jiang and Chen (2002), Hoof and Blocken (2009), Tantasavasdi et al (2001), Prasad and Fox (1996), BIM (2011), Ministry for the Environment (2008), Department of Education, Northern Ireland (DENI) (1998)and corp creator (1998)
AA3	Use nearby landforms and structures for wind protection and summer shading	Crobu (2010), Jefferson (1789), Capeluto (2003), Belakehal et al (2004), Lam (1997), Li (2007), BIM (2011), Ministry for the Environment (2008), Ahsan (2009), Krarti et al (2005), Hinkel et al (2003), Ip and Miller (2006) and (2009), The United States Air Force (2011), Ministry for the Environment (2008)

Table 4-1: End user Factors passive design functionality: Site end user factors

4.2.2 Building form

BIM (2011) refers to the tall and skinny building as a vertical form which can maximise PL. In addition to that, compact buildings can help to support and accurate both thermal comfort and cooling. This is what Ahsan (2009) points out: the compactness can minimise the surface area of the envelope which reduces heat gains. Figure 4:17 is an example of a compact building. Ahsan (2009) confirmed that natural ventilation can be achieved through using a building form that can be opened and outward oriented. Martin Pool Architects Munich (2011) designed a passive house in the city centre of Munich which is called Seitzstrasse, as shown in Figure 4:18. They consider the building to be compact especially in the warm zone area. In the section it is clear how they consider the passive ventilation to be provided vertically through a stack vent which

Figure 4:15: Compact building (Ahsan, 2009).

Figure 4:16: Passive compact building in Munich (section, site plan and perspective) (Martin Pool Architects Munich, 2011).

is the through path in each storey. Also, the perspective shows the number of windows on the façade.

The construction mass can influence optimum PLVT positively or negatively. The concrete centre (2010) referred to the role of low mass on effectiveness of rapid heat up or cooling. Based on this statement, this factor has been considered as one of the most essential factors of building form.

Building form is the second main stage in the PD process. This stage comes after the previous one, which is site investigation, orientation and landscape, is completed. There is no point of site investigation, if the building form which has been selected is not optimum. There are various forms that can help to maximise PL and PV. The United States Department of Energy (2000) referred to the need to consider the orientation, which should face 30 degrees to the south to maximise PL and PV. This cannot be achieved sometimes because there are several restrictions which can be obstacles. For example if the street is facing the north. In this case, the designer should try several forms without being restricted to one concept. The suitable form is selected based on the outside conditions and inside condition, on the one hand. On the other hand, designers should keep in their minds the safety of the building through simplifying the design, because the simple form will be clear and easy to observe.

There are several building forms which can enhance PDF at the same time as being simple. The various functions are difficult to achieve as each shape can have some functions but lose others or does not optimise them. Sigg et al (2006) classified the various forms from PLVT perspectives, as presented in Figure 4:19. This classification can help the designer to consider the rest of the functions which cannot meet the selected form as well as to be accurate when selecting the form of the building. BIM (2011) point out the several form types which can be used when designing PBD for optimising PLVT. Some forms can help to provide a lot of surfaces which of course can increase the possibility of providing windows. This can help the designer to optimise PL. The forms could be long, linear buildings, providing lots of wall surfaces that can be used for windows to improve PL and PV, and this can create interoperability between both functions.

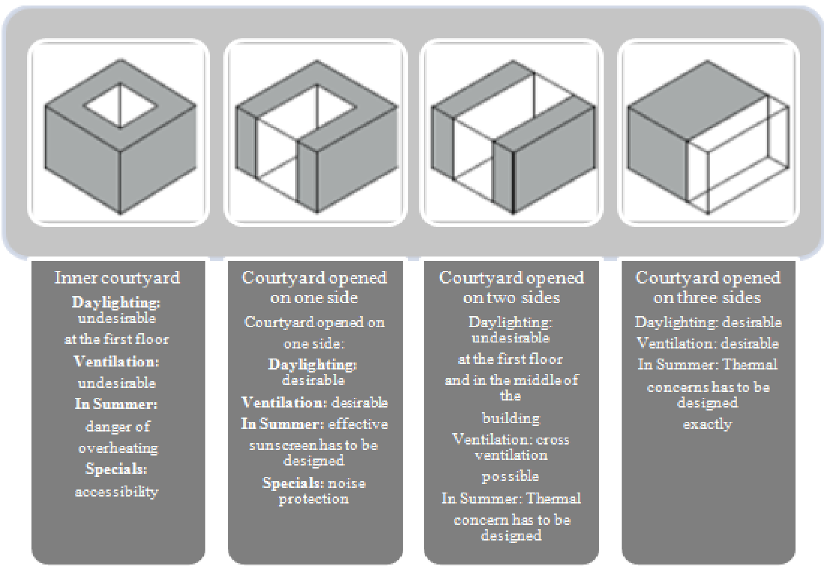


Figure 4:17: Various building forms (Sigg et al, 2006).

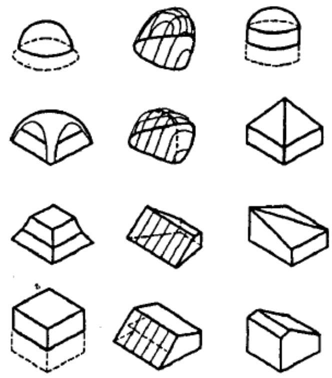


Figure 4:18: The various shapes (Prom et al, 1989)

The third example which includes the atrium in the core level achieves 100% of PL in each space. Baker and Koen (2002) identified some limitations that can help the building form to benefit from PL. The site is one of these limitations which can affect the building form. The topography of site, shape, size, legislation, planning code and sun obstructions are limitations which should be compliant for optimising PLVT. All of these limitations may have an important impact on the building shape to enable it to access the PL. Some approaches such as courtyards, atria, galleria, and light wells have been adopted into both older and modern buildings.

The volume of the building (geometry) and its surface are various and should be suitable to apply PDS (Prom et al, 1989). Prom et al (1989) said that the form should be suitable for thermal comfort, solar gain, and ventilation. The various shape types are summarised in Figure 4:20. Each type of geometry can help to apply PDS but there are differences on the level of performance in terms of LVT. The suitable shape is not limited to the three strategies but also could be in terms of the climate and seasons. The classification is shown in Figure 4:20 based on cold, temperature, hot/dry and hot/humid.

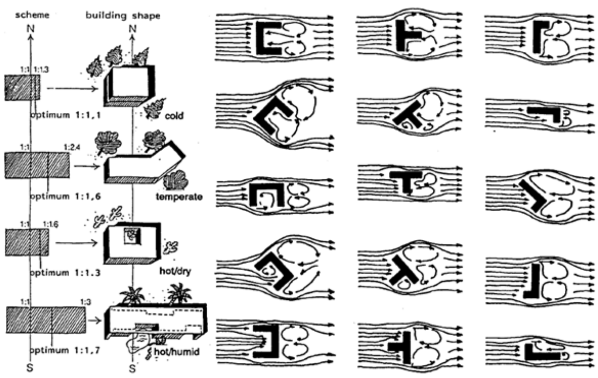


Figure 4:19: The suitable shapes based on climate and wind (Prom et al, 1989)

Prom et al (1989) added that the building geometry should be accurate in several levels, starting from the global, followed by the urban level, followed by the building level, and then the system level. In terms of the building level this could be in the suitable shape of the horizontal plan and vertical plan. Also, the building shape could be affected by the wind trend. For this reason, the designer should select the suitable shape based on an accurate wind analysis, as shown in Figure 4:21. Public Technology Inc and US Green Building Council (1996) confirmed that the building shape should minimise wind tolerance. For this purpose, the designer should take into account selection of the suitable shape, and shape of the building for maximum exposure to winter sun and summer breezes. Balasbaneh (2010) referred to using high mass to cool the space and that will be through using the building equivalent heat sink. Murray et al (May, 2009) referred to the use of high mass in traditional homes for promoting night ventilation.

Code	End User factors	References
AB1	Design compact building form for optimum heating and ventilation	BIM (2011), Ahsan (2009), Martin Pool Architects Munich (2011)
AB2	Use low mass construction to allow rapid	The concrete centre (2010)

	heat-up or cooling of structure	
AB3	Shape the building to maximise exposure to winter sun and summer breezes	United States Department of Energy (2000), Sigg et al (2006), BIM (2011), Baker and Koen (2002), Prom et al (1989), Public Technology Inc. and US Green Building Council (1996)
AB4	Use high mass construction with appropriate insulation to promote night ventilation	Murray etal (May, 2009), Balasbaneh (2010)

Table 4-2: End user Factors passive design functionality: building form end user factors

4.2.3 Space planning

The Ministry for the Environment (2008), the Department of Education, Northern Ireland (DENI) and corp creator (1998) all claimed that subdividing the building interior accurately separates heating and cooling zones. In terms of the spaces which demand PL, they should be located near to external wall access. At the same time, if there is more than one side access to an outside wall, should be optimised space orintation. The Ministry for the Environment (2008), the Department of Education, Northern Ireland (DENI) and Corp Creator (1998) claimed that the spaces that have similar functions should be interoperable together to benefit from PL. To avoid the complexity between open plan and division of spaces, the space should be able to be open plan or subdivided, especially with regard to spaces with similar functions.

PH can also be achieved by various strategies. PH should be considered and installed in a suitable way without creating any conflict between the interoperability of other PDS. There are different studies which refer to the ground of the space and its effect on PH. Kurtbas and Durmus (2008) classified the PH systems into four categories which are sun tempering, insulated gain, direct gain and indirect gain. The important part for the space planning is direct gain, which is the basic form of PH services. This system distinguishes when sunlight can be delivered to the space and heats the space as well as storing heat in the thermal mass. Central atriums, courtyards and lobbies (elevators, and stairs can be locate in central areas) can be used for optimum PV. It is also confirmed that the layout of the room, heating equipments, level of thermal insulation and air tightness (space) can influence the indoor environment. Fernandez-Gonzalez (2007) assessed five strategies for PH: wall trombe, sunspace, roof pond, direct gain and water wall, as illustrated in Figures 4:22 and 4:23. Water wall has been defined as a system which is mixed between indirect gain (traditional thermal storage wall) and direct gain strategies. This is because the water tank works as thermal storage. There are different approach-

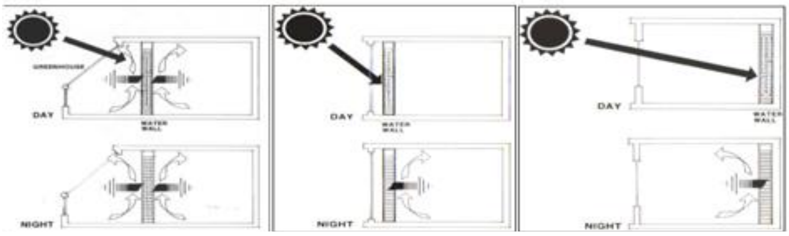


Figure 4:20: Combined direct and indirect gain for water wall, indirect gain and direct (Kurtbas and Durmus, 2008)

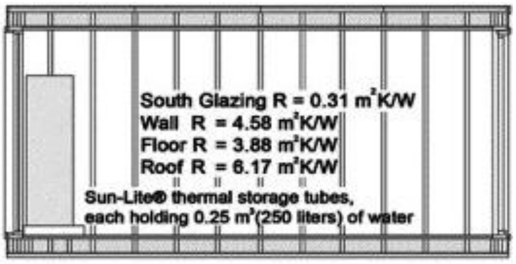


Figure 4:21: Water wall (Kurtbas and Durmus, 2008)

es for the water wall which could also work as direct gain or indirect gain or be interoperable. In terms of direct gain, Rodale (1980) said that the water wall stores the heating then it is released into the space at night. Indirect gain has the same process at night. The interoperability system works with the water wall where the side facing the sunshine can be heated directly and the interior space can be heated indirectly. The advantage of this system is that it can heat the space during the day and the night.

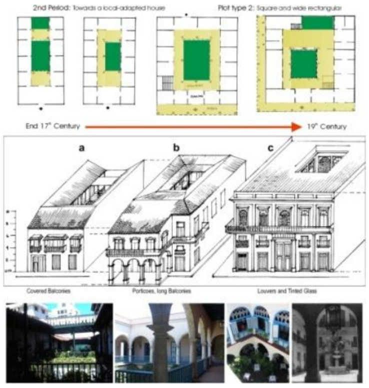


Figure 4:22: Central spaces (Tablada, 2009)

Some strategies could be impossible to use because they demand adequate space and enough area in which to operate. Courtyards and lobbies are a good example; they can be used to group service areas such as elevators, stairs and so on, as King (2009) said. Central spaces are one of the suitable traditional methods which were used to provide air ventilation into a space. The function of the courtyard can be divided into two functions which are mitigation of microclimate in the first place, then to make suitable internal thermal environments within the space and its surrounding rooms (Al-Azzawi, 1994). The majority of buildings in Old Havana included courtyards. This approach was adopted because the local climate was hot and humid. This has become the pattern of the city in order to meet the weather circumstances and because it is the only strategy available to achieve PH and to mitigate the hot feeling of EUs. Figure 4:24 shows the model of the compact housing and the different scales of using courtyards. The majority of building design in Havana considered adding courtyards in different stages. For instance, the houses of the wealthiest families were designed with one or two courtyards because of the width of the plot. The changes of building design and courtyard size was to achieve thermal comfort as well as to provide PV (Tablada, 2009). Providing PV to each space should be a clear demand and it is necessary to enhance indoor air quality. However, some spaces do not have a clear access to the outside. The United States Department of Energy (2000) suggested several strategies such as vertical air shafts/stacks, and central exhaust paths. These strategies should be optimised based on the building’s location, and interoperable with the space. There are also some strategies which help to deliver PV and PL to the interior spaces. However, these strategies could be impossible to use because they demand adequate space and enough area to be able to use them. Courtyards and lobbies are a good example; they can be used to group service areas such as elevators, stairs and so on as King (2009) said. Space planning covers the functionality aspects. Interoperability between several spaces should ensure that they work in harmony. Privacy should also be considered in space planning. BIM (2011) and the City of Santa Barbara Community Development Department (2006) claimed that designing open spaces helps to increase the possibility of air flow to

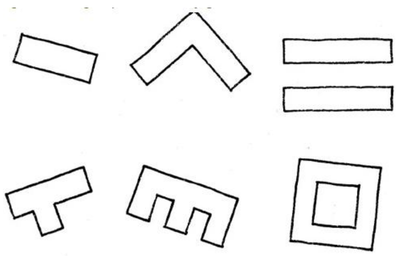


Figure 4:23: Long and narrow building form (Ministry for the Environment (1998-2011)

move through the interior of the space. For this reason, rooms, corridors and stairwells should be organised in a way that will be suitable for air movement through the building. Open plan can affect air flow function when it is going through the space. This has been referred to by Level (The authority of sustainable building) (2011). They claimed that use of open plan interiors promotes interior airflow. This is obvious, as there are no barriers to stop the air flow through the space.

The various shapes should be refined and tested before selection of the suitable form. The form should be interoperable with the site and the interior building to create a homogenous ecological system. This demands an accurate position and orientation and dealing with site topography. The form of the building could be vertical or horizontal extended.

The Ministry for the Environment (1998-2011) point out that using long or narrow sections can optimise PL, as shown in Figure 4:25. It is obvious that the inner courtyard and courtyard open from both sides are the same as Sigg et al (2006) said. But the rest of the form can be used to maximise PL and PV in cases where they are well orientated. In terms of the ventilation, it should be minimised during the winter. Balasbaneh (2010) referred to using high mass to cool the space and that will be through using the building equivalent heat sink. Li and Tsang (2008) stated that the accuracy of the size of the space and the rate of the depth compared to the height and width of the space is an important factor where the depth of the room from the window to the back wall should not be long. If it is too long half of the side of the room's back wall will be in shadow. This will not occur if the space is one storey or open plan, as light can be supplied from another point.

The situation of space planning can be divided into three categories as follows: firstly, the depth of the room with PL being provided from one side. Secondly, the depth of the room with PL being provided from more than one side - back wall, right or left. Finally, the depth with PL being provided from the roof plus one side or more. These are the limitations of the extent to which PL can be provided; and are only applicable in cases where the window is suitably located in the right place. The interoperability between total floor area and the window has been determined by Ihm (2009). The area of floor and size of window can affect the process of PL. For example, if the size of window is small this will lead to the provision of a low amount of lighting. Conversely, in the case of a larger window, the issue would not relate just to its size but also to the material used to finish the wall or window, whichwould affect the lighting efficiency. Some studies consider the size of space in three dimensions: height, length and width; and determine that achievement of an optical level of PL depends on the type of building. Li (2006) confirmed that the PL can clearly affect by the function of a space as well as EU visual and thermal comfort, as it gives brightness and enhances the EU's mood. Providing suitable PL can help to change the indoor environment to a more pleasing atmosphere. It can also help the EU to maintain visual contact with the outside world. This means the way of living can be changed positively. Mansy (2004) classified PL design systems for the building into eighteen categories. Six of them were for space planning and should be made accurately by the designer as follows: (1) Ground reflection is an important part: when the PL enters the space glare or comfort lighting can be expected. (2) Space orientation: this means how to consider the distribution of spaces through the development design stages; which means the designer should chose the most important space to face day lighting such a building store. This is supposed to be in each design. Any building going through the design process must be divided into two categories (A) Primary space with achievement of environmental conditions. (B) Secondary space with worse environmental conditions. (3) Form the ceiling if it is not at the same level such as a dome or slope. This is an essential point for architects to consider, especially those who think about the beauty of buildings, which is mostly a philosophical tendency. (4) Design of the space: if it is regular or irregular, rectangular or square; if it can help to allow the achievement of illuminating each part of the space or it will be an obstacle in some areas. (5) Reflectance of interior surfaces: this can be achieved through different approaches. For example, the reflectance can be by light and help to illuminate, on the one hand. On the other hand, the colour degree that has been used to paint the space should be selected carefully. In some cases the kinds of materials that have been used contribute to reflectance. (6) Height of the workplace above the floor: there is certain interoperability between the height of the work space and the PL efficiency. Considering the optical percentage for three dimensions of the space can facilitate the process of PL.

Space planning covers the functionality aspects. Interoperability between several spaces means that they should work in harmony together. On the other hand, Crobu (2010) divided the residential building into the most used rooms, such as the living room, situated to the south to benefit from the PL; and the least used to the north, as presented in Figure 4:26. The Ministry for the Environment (2008), the Department of Education, Northern Ireland (DENI) and corp creator (1998) refer to the importance of accurate dimensions of space and how they can help to maximise PL or PV. The latter author determined that ventilation provided on one side only can be effective at less than 7.5 metres. In contrast, the open plan design can have an affect up to 15 metres. In terms of the PL, it can be achieved up to 6-7 metres from the window.The Ministry for the Environment (2008) point out that the most used space should be located on the south to benefit from the PL and the least used space should be located on the north side. This could optimise both their function and interoperability. Interior space does not limit the group functions or division of the space or locations. There is another factor, which could affect the performance of PL and could deeply increase or enhance access, which is interior surface colours and finishes. For this reason, the designer should be accurate regarding the degree of the colours or the kind of finishes to be

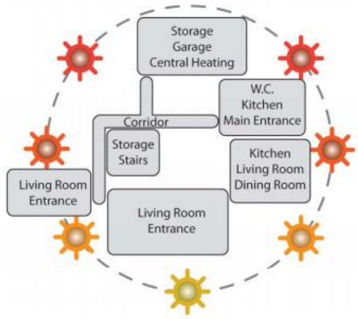


Figure 4:24: Optimal distribution of residential buildings (Crobu ,2010)

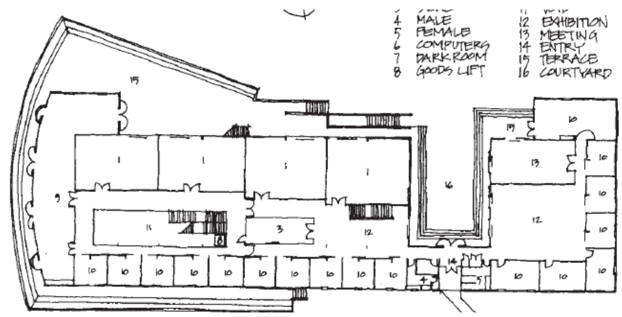


Figure 4:25: Space planning of Design Faculty Newcastle University (Prasad and Fox, 1996).

interoperable with PL strategies. For example, if the designer selected contrasting colours on the floor or wall, this could mitigate solar gain. The Ministry for the Environment (2008) stated that the suitability of the shape of the space can maximise the PV when the shape is narrow or long floor plan. This can be classified as an attenuate plan.

Sometimes the period when the space is in use can determine the division of the space. Usually from several resources the most used spaces will be on the south side whilst the least used spaces will be on the north. This cannot be generalised because it will be based on the function of the building; for example a residential building cannot be the same as an educational building. The Engineering Design Faculty of Newcastle University oriented the classes to the north to maximise the PH in the winter, as shown in Figure 4:27 (Prasad and Fox, 1996), because studying starts at the end of summer.

The City of Santa Barbara Community Development Department (2006) and the United States Department of Energy (2000) point out that the thermal mass should be suitably located to store heating whether in the wall or the ground for exposure to PL. Oriented and location of thermal mass helps to optimise PH and is part of interoperability and suitability.

There are several indicators that help to look into a deep plan to have lowest surface areas for heat loss. The dimensions of spaces play a big role in access of PL. Some spaces could have direct access to the outside but some of their areas could still be dark. Li and Tsang (2008) confirmed that the space plan can be part of increasing the efficiency of PL and the accuracy of its function through the depth of room, colours, and surface finishes. It has also been found that the area of the floor and the internal surface area can be PL strategies. This contrasts with the interoperability of both interior side and outside factors which can affect the amount of PL. This means that some factors cannot be considered whilst others are ignored, which means it is a cycle or chain. Different studies have referred to grouping the unimportant spaces in the back of the building and benefiting from them as buffer spaces to suit the building's function. One of the most important elements which is interoperable to both façade and space is sunspaces. This can work as a buffer space to some extent where its role is to filter the sunshine and lessen it before it enters the space. Different countries adopt this measure; one of them is in the UK, in Brighton, as illustrated in Figure 4:28. Ip and Miller (2006) explained the case study in Brighton and how the sunspaces can provide both sunlight and thermal comfort. The spaces' finishing can be part of the PH. This was found through the analysis of the case study of elderly people in Japan when it was noticed that in some houses the air conditioning is not used. There were many reasons for this; one of them is that the surface temperatures of the inner walls cause an increase in the temperature degree (Iino et al, 2007). Milne et al (2008) suggested organising the floor plan so that winter sun penetrates to as many spaces as possible during the daytime. To specify spaces could lead to top optimisation of solar radiation. However, at some stages the location and

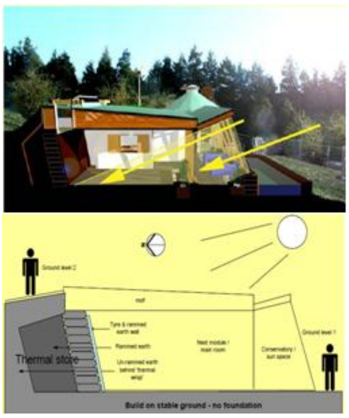


Figure 4:26: Sunspace Brighton (Ip and Miller, 2006)

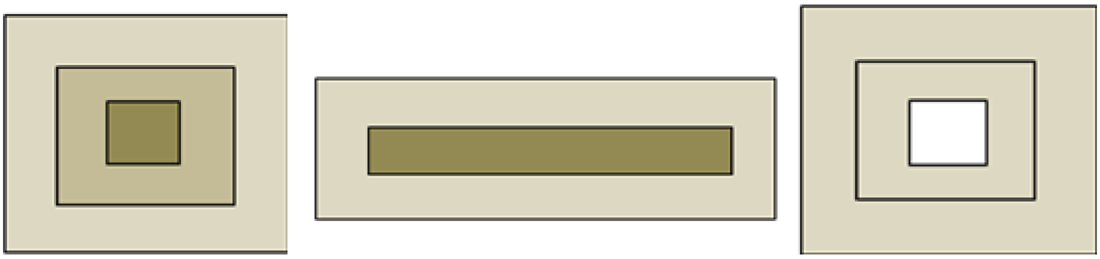


Figure 4:28: Square Shape, Rectangle Shape and Courtyard Shape

view could conflict with this target. For this reason, the designer should analyse the site and think of multi-solutions.

The Ministry for the Environment (2008) claimed that a long and narrow floor plate is preferred in order to help to maximise ventilation. At the same time it referred to the need of a suitable building mass to store heating. The function of a building's form is not only to identify the vertical and horizontal place dimensions but also to identify the floor area, whether or not it can access the PL, and if it can, by how much. Mostly, the first 4.5 m of the space can access the PL and the following 4.5 m can be day lit (Lechner, 2009). The form of the building can enable delivery of PL to the space or can be an obstruction. Lechner (2009) explained about building form when he made a comparison between three building forms which have the same area. The first example (as shown in Figure 4:29) was for the square shape which is solid and it has been divided into three levels in terms of PL. The rate of PL in the first level with a view to the outside space is 51%. The rate of incomplete PL in the second level, which is located between the last level and the core level, is 33%. Then the core area which accounts for 16% was dark. The second example (as shown in Figure 4:29) was for the rectangular shape, which included two levels. The proportion of PL for the first level was around 59%. However, the core level was dark and its rate is around 41%.

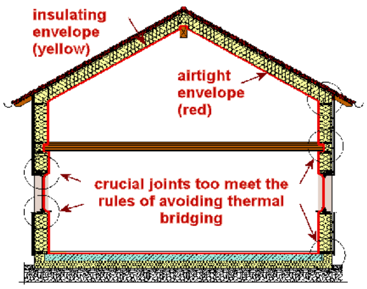


Figure 4:27: Insulation Opaqe building (Garcia-Hansen et al, 2002)

There are different studies which have referred to the ground of the space and its affect on thermal comfort. Garcia-Hansen et al (2002) mentioned the space and its interoperability with the three dimensions of PDS. This is when the designer does not optimise space orientation or design complex space. All of these factors can have an essential impact on the role of PH strategies and others. It can be seen from what has been introduced that the EU was not indicated clearly in their discussions, even though different studies have referred to the interoperability between EU and PH and consider EU as one of the pillars of thermal comfort.

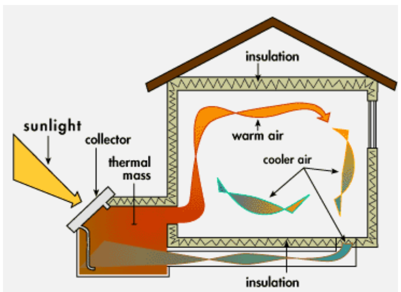


Figure 4:29:Thermosiphon (Garcia-Hansen et al, 2002)

Thermosiphon is introduced as part of PH, as presented in Figure 4:30 (Garcia-Hansen et al, 2002). This system deals with the space of the building. The process of this system is shown in Figure 4:30. Its process is that, in the first place, the sunlight is collected by the collector before transferring it to the thermal mass. There are two routes for the heat which collects to move to the space: through interoperability with the vents or through the ducts. As shown in the pictures, if the heat moves through the vents, all the heated air will enter directly into the space. However, the duct will help to move air through it and to convert it to cooler air, because the heated air will rise above the space and the cool air will be on the bottom. From this researcher's point of view, this system can create a balance between the hot and cool air, which will achieve EU ambitions about thermal balance. Feist et al (2005) referred to some suitable systems which can be installed to offer PH in the space such as insulation of opaque envelope and thermal bridge free construction, as seen in Figure 4:31. These two systems can be protecting the wall, roof and the floor as well as keeping the interior space warm. The Ministry for the Environment (2008) stated that the suitability of the shape of the space can maximise the ventilation especially when the designer designs a narrow or long floor plan. This is an attenuate space plan. Ahsan (2009) pointed out that openings are one of the important elements for the admission of air flow and to provide cross-ventilation. For this reason, it should be accurate when designers select and use it and consider its interoperability with the space. There are various PV strategies. Stack ventilation is one of them, which enhances ventilation in the building design (King, 2009). A definition of stack ventilation is "*Stack ventilation is where air is driven through the building by vertical pressure differences developed by thermal buoyancy"(* Baker, 2011). The cooling air outside is more dense than the warm air inside the building. For that reason it will escape from openings high up in the building envelope (Baker, 2011).

Code	End User factors	References
AC1	Subdivide interior to create separate heating and cooling zones	Ministry for the Environment (2008), Department of Education, Northern Ireland (DENI), corp creator (1998)
AC2	Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	Kurtbas and Durmus (2008), Fernandez-Gonzalez (2007), Rodale (1980)
AC3	Use central atriums, courtyards and lobbies (elevators, and stairs can be located in central areas) for optimum ventilation	King (2009), Al-Azzawi (1994) , (Tablada, 2009)
AC4	Provide vertical air shafts/stacks, and central exhaust paths to promote interior airflow	United States Department of Energy (2000), King (2009)
AC5	Use open plan interior to promote interior airflow	BIM (2011) and City of Santa Barbara Community Development Department (2006), Level (The authority of sustainable building) (2011).
AC6	The proportion of the plan is long and narrow (use linear plan form, or a similar strategy) to optimise day lighting	Ministry for Environment (1998-2011), Sigg et al (2006), BALASBANEH 2010, Li and Tsang (2008), Ihm (2009), Li (2006), Mansy (2004)
AC7	Organise rooms, corridors, stairwells in a way that uploads a low resistance airflow path through the building	BIM (2011), City of Santa Barbara Community Development Department (2006), Crobu (2010), Ministry for the Environment (2008), Department of Education, Northern Ireland (DENI), corp creator (1998), United States Department of Energy (2000), (Prasad and Fox, 1996)

AC8	Consider interior surface colours and finishes for optimum day lighting	Li and Tsang (2008)
AC9	Design plan to create buffer zones from the summer radiation	Ip and Miller (2006), (Iino et al, 2007)

Table 4-3: End user Factors passive design functionality: space planning end user factors

Code	End User factors	References
AC10	Plan specific spaces or functions to coincide with solar orientation	Milne et al (2008)
AC11	Narrow floor width to optimise natural ventilation	Ministry for the Environment (2008), Lechner (2009)
AC12	Provide solar-oriented interior zone to store and maximise solar heat gain	Garcia-Hansen et al (2002), Kurtbas and Durmus (2008), Feist et al (2005)
AC13	Attenuate plan to promote ventilation	Ministry for the Environment (2008)
AC14	Link the exterior and interior airflows by single-sided, cross or stack ventilation	Ahsan (2009), King (2009), Baker (2011)

Table 4-4: End user Factors passive design functionality: space planning end user factors

4.2.4 Roof

A space's roof can play a big role on PD. Several elements of roof natural ventilation have been used to provide adequate PV. These elements are part of architecture which are distinguished from other ventilation concepts. Also, the cost of implementation is simple without affecting ventilation performance. Many approaches have been adopted to provide PV through harnessing the PV and PL into the building. Most of these approaches were results of traditional architecture.

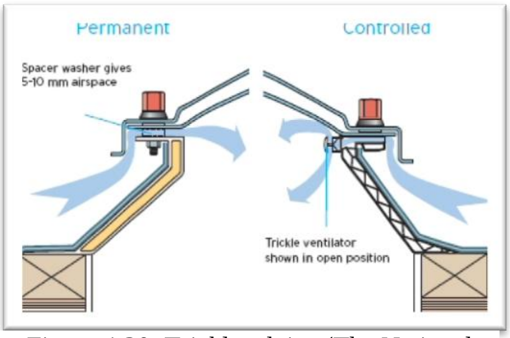


Figure 4:30: Trickle advice (The National Domelight Company, 2009)

A trickle advice is one of devices of PV which has been used to minimise energy consumption. This technique has been used commonly in Europe. Trickle dvice can be in the roof in some cases to accurately control the air inlet and outlet, as shown in Figure 4:32. Usually, it is interoperable with the skylight to provide PV to the space; and for the skylight to operate safely the gap around the complete perimeter should be between 5-10mm (The National Domelight Company, 2009).

At the same time, the roof should be well-insulated in order to decrease the temperature loss from the interior building. In addition to that, the accuracy of shape and slope angle can help to remove water when it is raining. Considering the orientation of the roof also helps to optimise ventilation.

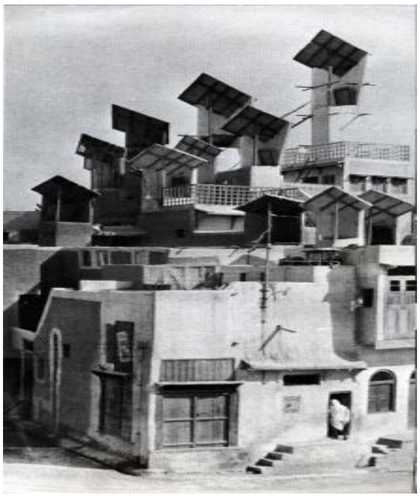


Figure 4:31: The different level of scoop in Pakistan (McDonough, 2002).

Wind scope is one of PDS. Wind scoops and wind cowls are synonymous with each other. Wind cowl can be defined as a general name for roof structure ventilation (Khan et al, 2008). Wind scoop is a device which collects outside air inside a space, which is the reverse function of wind towers. In this case, the building's roof is an essential part of the building in which to install this system. Sometimes it can be installed in the landscape to provide the air into the building through embedded ducts (Kleiven, 2003). There are many case studies which have applied wind scoops such as houses in Hyderabad in Pakistan from 500 years ago (see Figures 4:33 and 4:34). The process was to catch the air pressure and direct it to the space. The wind scoop's location is above the roof of the housing because it needed to be higher to accurately catch the required wind speeds. Wind scoops can also be provided in another way: through a tube in the ground, which will supply the place (McDonough, 2002).

Figure 4:32: The widespread use of wind scoop to the same direction (McDonough, 2002)

BIM (2011) point out the importance of the location of roof ventilators, skylight and vent shafts. Some of these elements are dual function (interoperable) and can be used for natural illumination and ventilation, such as skylight, clerestory and light tube. These elements should be focused on in terms of the security and accuracy of their installation. A skylight is defined as a horizontal opening on the roof to provide lighting (Baker, 1993). Garcia et al (2002) claimed that there are benefits from opening a skylight to provide ventilation to the space. This means that this element (skylight) can perform two functions, so it is interoperable. This is the same as the situation with duct ventilation which combines heating and ventilation in the same element. The main function of a clerestory is to allow the sunlight to light the space. Also, it can be used to provide ventilation to the space, which means interoperability of two functions of PD. Garcia et al (2002) confirmed that a clerestory allows ventilation to enter into the space. They are defined as the tilted or vertical openings and their place is on the roof of a building, as shown in Figure 4:35. Usually, a clerestory is vertical or a tilted opening from the roof. Its function is similar to the roof

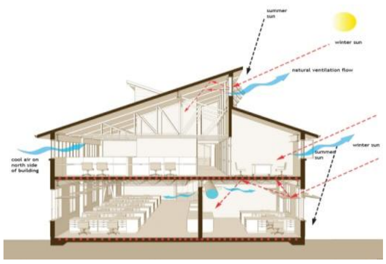


Figure 4:33: Clerestory (American Institute of Architects, 2009).

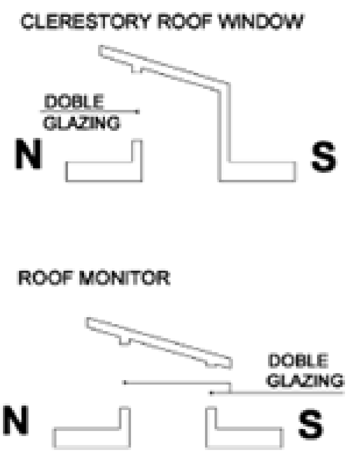


Figure 4:34: Clerestory and roof monitor (Garcia-Hansen et al, 2002)

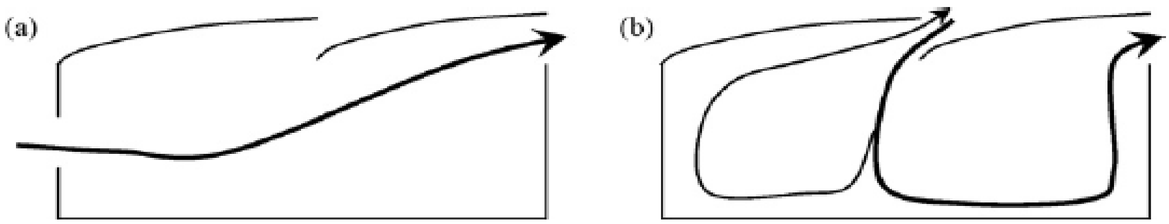


Figure 4:35: Saw tooth air movment (Kacira et al, 1998)

monitor's function in terms of illuminating the space as well as ventilation and heating (Garcia-Hansen et al, 2002), as presented in Figure 4:36. In general, a saw tooth is used to light the space through the roof. In some cases it can be used as ventilation when it involves window opening. Kacira et al (1998) concluded that the ventilation of the building can enter through the windward side openings and cross the greenhouse from one side to another. In case the windward openings are closed, the saw tooth can vent the space through its opening and exit through the same opening. Kacira et al (1998) confirm that the best accuracy of efficiency function is in the first case when the windward side is opening. In the second case, the average amount of ventilation can decrease from 80% to 90%, as shown in Figure 4:37.

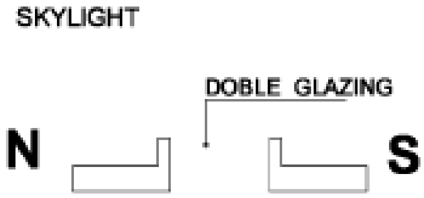


Figure 4:36: Skylight (Garcia-Hansen et al, 2002)

This system is placed on the roof and includes the sloping roof and vertical glass to allow natural light to enter into the space to optimise its function. Then the vertical glass window needs to be shaded: usually the sloop roof extends to shade it. The extension is used as an overhang against direct sun (Natural Frequency, 2011).

A skylight can be defined as an opening area which is placed on a horizontal place or slope roof, as per Baker et al (1993); and this is illustrated in Figure 4:38. Its main function is to provide PL, but it has another function which is ventilation in some situations, where it needs to be movable. The problem is in summer it needs to adapt some shading devices to mitigate the sunshine. PV and PL techniques are usually developed separately; however, in some techniques they are interoperable in order to achieve demands of both lighting and ventilation. Skylight and sun pipe are good instances. This element can be transparent in order to allow PL into spaces; especially those previously unreached by PL. Bouchet and Fontoynont (1996) claimed that there is interoperability between EU feelings and PL as well as the fact that PV is able to change EU feelings. This means PL and PV can affect the EUs' performance.

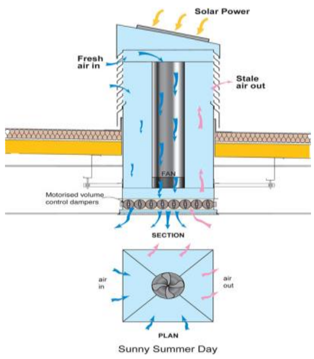


Figure 4:37: Sun pipe combination system (RH and Construction, 2009).

There are many systems and approaches which can be classified as sun pipe. Kim and Gon (2010) divided the sun pipe system into different categories, as shown in Table 4-5. Figure 4:39 shows the

Figure 4:38 : Seaside Primary School in Lancing, West Sussex (RH and Construction, 2009).

sun vent pipe which involves two pipes as follows. The channel is used to provide air flow to the space and out of the space. The entrance is used to allow an amount of sun to enter the space and the top of the pipe is covered by a transparent dome where the pipe surface is covered by material film (Oliveira, 2001). Seaside Primary School in Lancing, West Sussex is a good example of this type of combination, as presented in Figure 4:40 (RH and Construction, 2009). Bansal et al (1993) confirmed that the solar chimney plays a big role in providing air ventilation. They also identified the value of air flows by three factors as follows: geometry of collector, cross-section of the duct, and the extent of the performance parameters of the air collectors.

Roof overhang is one of the strategies which can be part of ventilation and PL. Ahsan (2009) indicated that roof overhang can enhance indoor air quality through providing shading and changing the air flow direction. In addition to that, its size can be enhanced to protect the walls from radiation as well as the surface openings. It has been confirmed that it needs to be made using lightweight materials with high reflectivity. PV panels are widely used to store solar access (ARUP, 2012). The Department of Education, Northern Ireland (DENI) and corp creator (1998) concentrated on the importance of evaluating the security of the roof lighting and selection of glazing to avoid overheating.

BIM (2011) clarified that the roof glazing should be very well insulated to mitigate heat loss. There are several methods of PV such as roof garden, roof pond and thermal insulation. The performance of the trombe wall is lower than that of the solar roof design in hot climates where the temperature is very high. In a simple sense, this is because the roof solar collector can optimise higher air temperature (Awbi, 1998). In terms of the concrete slab, it can be added to the insulation layer by taking into account the gap between the two. This can affect the thermal performance in the summer time. The roof insulation can help to mitigate the harsh solar heat (Dimoudi, Lykoudis and Androutsopoulos, 2006).

The heating system for both air and water is installed to suit EU needs as a source for both heating and cooling systems (Chan, Riffat and Zhu, 2010). This reflects the importance of the EU at the design stage and how they must be considered and taken into account as well as other functions. Roof monitors and clerestoreys have the same function. Roof monitors can be defined as a high portion of the roof which is open from north and south directions. The main function is to allow lighting to enter into the low level of the space in order to increase the luminance level, plus allowing PV through the open window (Garcia-Hansen et al, 2002). Using a ventilated double roof is one of the roof solutions for providing optimum PV. This should be accurate to help the air enter between the different layers of the roof without entering the space, as shown in Figure 4:41 (Gut and Ackerknecht, 1993).

Type	No	Sub-Type	Description	Photo
Natural ventilation and day lighting	1	Sun Catcher	This can provide day lighting and ventilation from different directions. The technical details can provide stack ventilation and natural buoyancy.	
	2	Movement sun catcher	This technical approach compacts both sun catcher systems. It is preferable to apply it in small spaces.	
	3	Solar	This technique combines three systems together: fluorescent light, sun pipe and natural ventilation. It is often used for utility area and bathrooms.	
Day lighting	1	Sun pipe	There is no limit in length or number of bends. This technique is 98% reflective tube.	
Day lighting (Brighten up)	1	Solatube 160 DS	The tube length is six metres and the light coverage area is between 14 and 19 m^2.	
	2	Solatube 190 DS	The tube length is 9 metres and the light coverage area is between 23 and 28 m^2.	
Day lighting (Sola-Master)	1	Solatube 21-C	The round tube is converted to a square diffuser on installation.	
	2	Solatube 21-O	This technique is distinguished by not having a finished ceiling and by a less obtrusive roof opening.	
Day lighting (SolaMaster)	1	Rigid	This system differs from the others by its bright, white light and flexibility.	
	2	Flexible	This system is similar to the Rigid one but it is quick and easy to install.	
Day lighting (Rectangle shape)	1	Rigid	Its length is around 1950mm and 4mm tough glass is used for the top dome.	
	2	Flexible	Its length is around 1950mm and 4mm tough glass is used for the top dome.	

Table 4-5: Various sun pipes (Kim and Gon, 2010)

The case study of Hyderabad looks at a traditional system. Wind scoops have been installed in the shopping mail (Blue Water shopping centre) in Kent in the UK using modern materials (aluminium as well as transparent to provide lighting), as presented in Figure 4:42. The main function is to direct air to the space to create high efficiency in the mall (McDonough, 2002). Elmualim (2006) pointed out that the design of wind scoops in the mall was based on the traditional approach used in Kent houses, as shown in Figure 4:43. This approach was developed until it became the architectural standard for buildings around Kent. The designers must accurately predict the height of windscoops to provide the correct amount of air which cannot be provided through the window. Also, the scoops should all be on the same side of the building, and all directed at the prevailing wind.

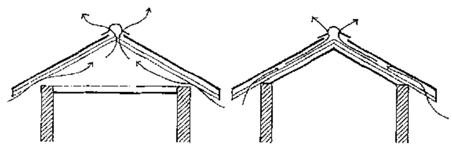


Figure 4:39: Double roof ventilation (Gut and Ackerknecht, 1993)

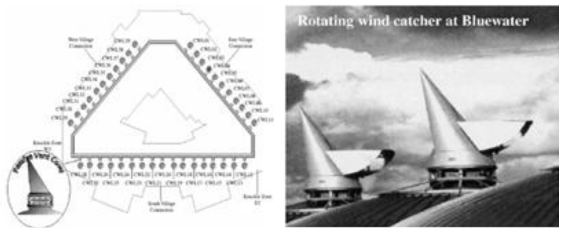


Figure 4:40: The spread of windscoops on the roof of shopping mail on Kent, UK (McDonough, 2002)

Qatar University has included this technique to combat the harsh climate in Qatar. The designers chose this method in order to add another value to the building, which is aesthetic value, as shown in Figure 4:44 (Sayigh et al, 1998). The spread and convergence of wind catchers give the impression that its role is to guard from the harsh conditions (Al-Shaali, 2002). The designer uses the wind catcher to provide PV into the university spaces. Also, other aspects such as courtyards were included. All of these aspects have led to high levels of efficiency because they are installed in the suitable positions. Opening the wind catchers from each side enables accurate provision of wind into the building. Duct ventilation is installed in the roofs to accurately provide air ventilation; usually it is interoperable between the roof and the centre of the building or space. On the top of the duct a fan is installed to draw air into the building (Odeh, 2006). The duct was installed to achieve two functions which are fluid transport and heat recovery. In some cases, the chimney can be used based on the method of its installation (Manz et al, 2000). For example, when the warm air rises in the place it will be replaced by cool air through this technique. Usually, it is used in bathrooms and kitchens (Greenspec, 2010), as shown in Figure 4:45.

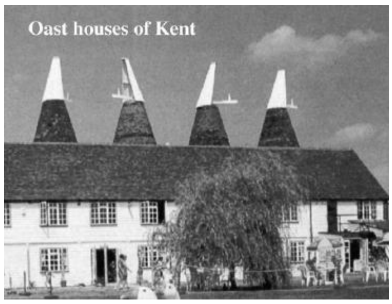


Figure 4:41: Traditional wind scope (Elmualim, 2006)

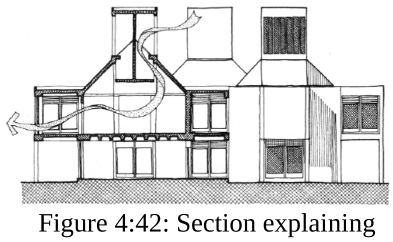


Figure 4:42: Section explaining wind movement through the building (Sayigh et al, 1998)

Some roofs or their elements can be suitable for one level or for many in case the building has courtyards or lobbies. In other cases, roofs and their elements cannot help other storeys or space. For this reason, there are several measurements that should be accurate and suitable when designing the building roof. The angle and shape of the roof should be suitable and accurate for optimum PV and PH. Both the United States Department of Energy (2000) and Ahsan (2009) referred to the importance of the roof angle and its shape; how it can help to admit lighting to the interior building. The Faculty of Design building of Newcastle University used a saw toothed roof to provide optimum PL (Prasad and Fox, 1996), as shown in Figure 4:46. Roof angles can be effective in PV, especially with regard to accurate orientation to the prevailing wind. Biwole et al (2008) investigated the impact of angle of slope on the degree of temperature and the air movements on the channel exits. They found that the temperature decreases and the air velocity increases when the angle of the roof rises. In terms of PV, Susanti et al (2008) confirm that increased roof slope can affect the accuracy of the PV which means decreasing the degree of temperature.

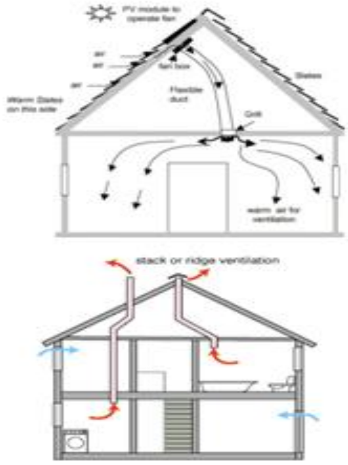


Figure 4:43: Duct ventilation (Odeh, 2006 and Greenspec, 2010).

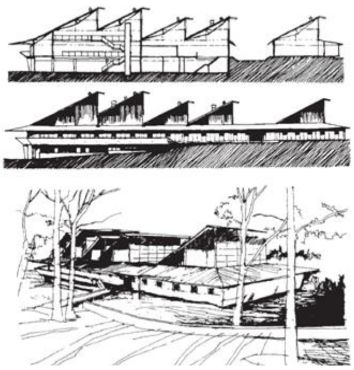


Figure 4:44: Saw tooth roof of The Design Faculty building of Newcastle University (Prasad and Fox, 1996)

As can be seen from the discussion above, the sloping surface is very important in the provision of PV and PH. For this reason, it can be said that accuracy of the roof angle must be taken into account during the design process to see if it is possible to apply and ensure that it complies with local regulations.

Code	End User factors	References
AD1	Use roof elements for stack effect ventilation	The National Domelight Company (2009), Khan et al (2008), Kleiven(2003), McDonough (2002)
AD2	Use skylight, light tube and clerestory for natural illumination	BIM (2011), Baker (1993), Garcia et al (2002), Kacira et al (1998), (Natural Frequency, 2011), Baker et al (1993), Bouchet and Fontoynont (1996), Kim and Gon (2010), Oliveira (2001), RH and Construction (2009), Bansal et al (1993), Ahsan (2009), ARUP (2012), Department of Education, Northern Ireland (DENI), corp creator (1998), BIM (2011)
AD3	Use solar roof collectors on the south-oriented surfaces	Awbi (1998), Dimoudi, Lykoudis and Androutsopoulos (2006), Chan, Riffat and Zhu (2010), Garcia-Hansen et al (2002).
AD4	Use double roof and wall construction for ventilation within envelope	Gut and Ackerknecht (1993)
AD5	Use ventilated roof to lower summer gains through roof	McDonough (2002), Elmualim (2006), Sayigh et al (1998), Al-Shaali (2002), Odeh (2006), Manz et al (2000), Greenspec (2010)
AD6	Use of an appropriate shape and angle of the roof for optimum ventilation and thermal comfort	United States Department of Energy (2000), Ahsan (2009), Prasad and Fox (1996), Biwole et al (2008), Susanti et al (2008)

Table 4-6: End user Factors passive design functionality: Roof end user factors

4.2.5 Façade and envelope

The façade and envelope is the link between the outside and inside of the building when the building benefits from the surrounding environmental design, which can control the amount of air flow or solar access. Several of these measurements should be able to respond to the outside climate for optimum PD. In terms of the ratio of the glazing, it should be accurate in a way that benefits from PL and PV without creating any overheating or cooling, as BIM (2011) claimed. Bateson and Hoare Lea (2001) point out the importance of accurately predicting the rate of glazing needed on the façade, as it can lead to appreciable heat loss and solar gain. The Department of Education in Northern Ireland (DENI) and corp creator (1998) determined that the minimum rate of vertical glazing is equal to 20% and its maximum is 40% whether on an internal or external wall. For this reason, glass area should be optimised for PL and solar gain. Heat flow is one of the most important issues on the envelope which should be considered through appreciation of the selection and location of materials. The City of Santa Barbara Community Development Department (2006) points out the importance of selecting high quality materials for optimum PH. ARUP (2012) states that optimum façade can be through the interoperability of three layers of clear glass, with the inner layer forming a cavity containing movable blinds.

Glazing is a feature which has been used in façades or openings and doors. For this reason, its specification should be accurate. Several authors have referred to it from various angles. The United States Department of Energy (2000) said that consideration of the orientation of the glass and its size should be accurate in order to optimise winter heat. It is also said that each façade should be selected suitable glass which is different from the other façade. At some stage, it has been suggested that'the suitable rate of glass between the floor area and the glazing should be equal to 7%. The glass on the south should be accurate for balancing of heat gain and heat loss without causing overheating. The glass on the west, east and north façades should be a suitable size to enable high visibility. Insulation should be used to keep heat inside the building (Ahsan, 2009).

The performance of the trombe wall is lower than that of the solar roof design in hot climates where the temperature is very high. In a simple sense, this is because the roof solar collector can more accurately predict the existing air temperature (Awbi, 1998). An interoperable shading strategy with a double skin façade is one of the strategies which are used for optimising PL and PV where the shading devices reduce both undesirable natural light and heat gain (Bateson and Hoare Lea, 2001 and Ahsan, 2009). The mount of the openings on the façade should also be considered based on the orientation and the demand of the PL and PV on the space. Ahsan (2009) and the Department of Education et al (1998) indicated that one of the limitations is to avoid openings on the west façade except if using any shading devices, to minimise heating of the space. The Department of Education et al (1998) referred to several strategies that could be used on the south façade to avoid excessive solar gains, such as overhanging eaves, external shading or recessed windows. The interoperability of several of the PV strategies should be taken into account by designers. The PV strategies are such as atriums, double skin façades, ventilation and solar chimney and night purge (Ministry for the Environment, 2008). Minimising envelope openings leads to minimising overheating. The United States Department of Energy (2000) referred to reducing window area in three façades - east, west and north - to minimise heating in hot climates. This cannot be generalised because in cold climates the maximum window size should be to the south. Optimum size is balanced between the three aspects of PD without any conflict. BIM (2011) and the City of Santa Barbara Community Development Department (2006) referred to the fact that providing windows enhances the removal of unwanted heating. Size of the window can play a big role in maximising the ventilation or solar access or both. Ahsan (2009), the Department of Education, Northern Ireland (DENI) and corp creator (1998) stated that PV and PL could be improved by increasing window size on the wall.

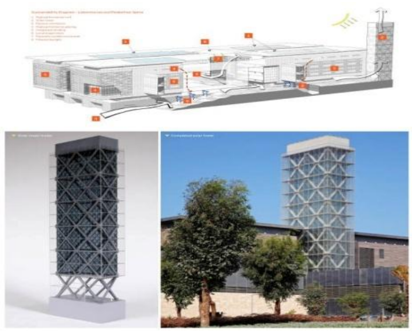


Figure 4:45: (top) Solar Chimneys ventilation diagram in the King Abdullah University of Science and Technology (Carboun, 2010).

One of the definitions of a solar chimney is a kind of renewable energy that optimises PV of a building. It can be installed in the building in two forms - on the roof or on the south façade (Miyazaki, 2006). A solar chimney can work as an element of PV. It is also used as primary ventilation. It can be said that it has been successful in different projects. On of them is Coventry Library, as shown in Figure 4:48. The accuracy of this element led to increasing the cross of stack ventilation during the summer season (Santamouris, 2007). In the King Abdullah University of Science and Technology, the wind towers and solar chimney are interoperable to achieve the same functions, as illustrated in Figure 4:47. The solar chiemny is directed to the prevailing Red Sea to provide PV into the university as well as to achieve a high level of PH (Carboun, 2010).

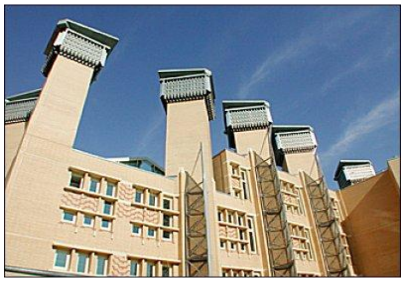


Figure 4:46: Solar Chimney Coventry library (Santamouris, 2007).

Hendriksen et al (2000) defined an architectural phenomenon which is driven from the beauty of a building when the whole façade is covered by glass. The main reason to apply this kind of façade is to allow the EU of the building to see as much as possible of the surrounding area and building (2000). Gratia and Herde (2007) proposed guidelines to achieve best ventilations through the selection of a suitable double skin façade accurately to

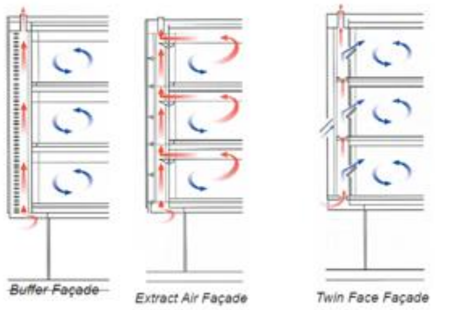


Figure 4:47: Various types of double skin facade (Boake, N/A)

provide PV. In their study, they considered two routes to achieve their guidelines in the cases of whether the façade is sunny or is not. Boake (2007) classified the double skin façade into three types as follows: buffer façade, extract air façade and twin face façade, as shown in Figure 4:49. The City of Santa Barbara Community Development Department (2006) and the United States Department of En-Energy (2000) point out that the thermal mass should be suitably located to store heating whether in the wall or the ground to increase exposure to PL. Orientation and location of thermal mass helps to optimise heating and is part and parcel of interoperability and suitability. Window openings play a big role in the provision of wind ventilation into the building (Karava, 2007). In the summer time, the high building is ventilated through the windows; this process is wind driven and is the main cause of airflow. This is the first point for PV strategies. There are three dimensions which can affect the efficiency of PV strategies for windows and which should be accurately designed by designers, as follows: the number of windows, the locations of windows and the size of windows. The numbers of windows on the façade can provide ventilation or meet the demands for ventilation but this is depending on their distribution on the façade. There are various authors who indicated the importance of the south wall façade. Künzel and Sedlbauer (2001) stated that the south oriented wall is warmer during the whole day. This is an indicator to which the designer should pay attention when they install an element or strategy.

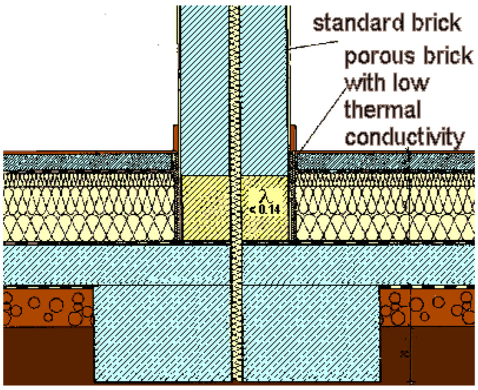


Figure 4:48: The bridge insulation (Lamar ,2006)

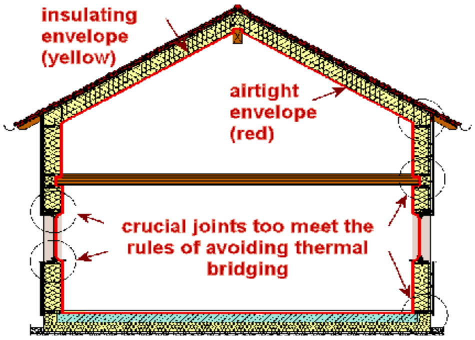


Figure 4:49: Insulation of opaque envelope (Lamar ,2006)

Lamar (2006) declared that the main function of a thermal bridge is simply to mitigate losing heating, as presented in Figure 4:50. This is in case the envelope of the space is controlled air heating and there are no infiltrations of heat through it. As shown in Figure 4:5,1 the insulation of the space’s walls is to guarantee keeping the temperature constant, as far as it is possible, because of course the temperature cannot always be kept at the same level, but it can be controlled. This system is used to offer comfort in the occupants’ space which will impact on their performance and efficiency and will result in the improvement of their psychological comfort. There is an important point, which is part of this research, about who uses the space and their age and health. For instance, in terms of health, elderly people can be affected by the lower humidity, which helps to increase the probability of catching influenza and also makes the skin dry. According to Iino et al (2007), the most utilized space for elderly people in Japan is the living room. This confirms one of the purposes of PH which is the time of using the space. All of these parameters must be considered and at the early stage of designing the space, and the designer must have a high degree of awareness about this aspect.

The Ministry for the Environment (2008) and Bateson and Hoare Lea (2001) point out the possibility of interoperability of glazing types with shading devices in order to control solar gain and glare, which is, one way or another, harmonisation. The designer should be accurate with regard to their location and interoperatility to ensure avoiding any conflict between them. Shading strategies are one of the most important features which have clear impacts on PDF. As has been referred to, selecting appropriate glazing for each façade shading device should also be accurate based on its orientation and compliance with site circumstances (Ministry for the Environment, 2008). Several of the shading strategies are essential to minimise solar gain and maintain the interior PH to enhance health and safety. This will create a balance between the indoor and outdoor environments. This can be through benefiting from the outside conditions. The variation is summarised in Table 4-2.

The devices for shading and mitigating the PL are different depending on their function as well as their position. Light shelves are interoperable with the performance of PL, as Franco (2007) stated. The light shelf can help to reduce the sunshine. There are also some limitations which can accurately control the PL cycle or not, such as the size of shelves, their material, the position and the angle. These limitations must be considered and taken into account through the design process from the concept to the final drawing. The façade generally and its sub-elements' design can be called the main control in the process of PL. The shelves have been divided into different types by Aghemo et al (2008): balconies, side fins and bay windows which have been grouped by Li et al (2006), as presented in Table 4-7.

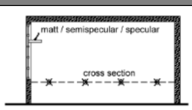
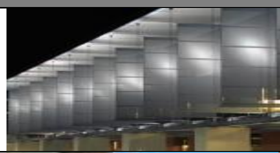
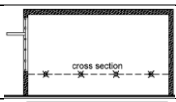
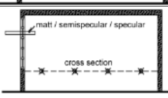
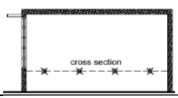
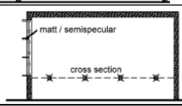
Shading devices	1	**Shading devices**	2
Internal light shelf		Side fins	
External light shelf		Balconies	
Internal and external light shelf			
Overhang		Bay windows	
Horizontal fins			

Table 4-7: Shading strategies (Li et al, 2006)

Gooch and Bickert (1999) referred to the role of the louvred wall for enhancing control of PV. Based on this view it has been considered in this research as one of the most important strategies that needs to be taken into account for providing optimum PV.

The glaze can enhance the ventilation. It has been referred by ARUP (2012). It is said that using a thermal glazed chimney can help the function to accurately draw the external air through a building structure if the whole building is south facing. To ensure the accuracy of every element of the façade, the selection of the material has to be considered, with regard to both quality and type. Using high capacitance materials to store heating greatly enhances the performance of the function. The Ministry for the Environment (2008) referred to the importance of considering PH implications of PL design, as it is important to accurately select materials for optimum PLVT. It is important to control air infiltration. Several authors agree on the importance of developing details to minimise air infiltration and exifiltration. Light shelves are one of the solutions which can be interoperable with the façade in order to help to deliver optimum lighting to the deep space. Ahsan (2009), the Department of Education, Northern Ireland (DENI) and corp creator (1998) referred to the importance of light shelves where they can help and work on large windows to improve distribution of sunshine and reduce PL contrasts. Lechner (2009) confirms that the window can be good or bad depending on the pressure distribution, which varies with wind direction. The importance of installing fin walls which work at 45 of wind direction has also been highlighted. Halliday (2008) indicated that windows that open should be larger and higher up to get the same amount of ventilation in each storey. It has also been mentioned that the different functions of opening windows plus the ventilation are to offer a good view, shade and light, as well as to achieve EU satisfaction. The types of windows can be classified into different types such as single-sided, single-opening, double opening. Ahsan (2009) indicated that several strategies should be accurate with regard to the façade and building envelope, as follows: insulation, thermal mass, colour of external walls, glazing systems, window size and shading devices.

Code	End User factors	References
AE1	Minimise the ratio of exterior surfaces to interior floor areas	BIM (2011), Bateson,A and Hoare Lea,P (2001), Northern Ireland (DENI), corp creator (1998)
AE2	Use high-capacitance materials to store solar heat gain and control heat flow through envelope	City of Santa Barbara Community Development Department (2006), ARUP (2012)
AE3	Optimise south-facing glazing	United States Department of Energy (2000), (Ahsan, 2009)
AE4	Use Trombe wall or double façade to collect solar gain	Awbi (1998), Bateson and Hoare Lea (2001), Ahsan (2009), Department of Education et al (1998), Ministry for the Environment (2008), United States Department of Energy (2000), BIM (2011), City of Santa Barbara Community Development Department (2006), Ahsan (2009), Department of Education, Northern Ireland (DENI), corp creator (1998), Miyazaki (2006), Santamouris (2007), Carboun (2010), Hendriksen et al (2000), Gratia and Herde (2007), Boake (2007)
AE5	Locate thermal mass inside the envelope to store heating	City of Santa Barbara Community Development Department (2006), United States Department of Energy (2000)
AE6	Minimise openings in envelope to reduce thermal gain	Karava (2007)
AE7	Use solar wall on south-oriented surfaces	Künzel and Sedlbauer (2001)
AE8	Develop details to minimise air infiltration and ex-filtration	Lamar (2006), Iino et al (2007)
AE9	Provide shading strategies for walls exposed to	Ministry for the Environment (2008), Bateson

	summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort	and Hoare Lea (2001), Franco (2007)
AE10	Use louvred wall for maximum ventilation control	Gooch and Bickert (1999)
AE11	Use exterior elements to direct summer wind flow into the interior	Santamouris, 2007
AE12	Orient openings to facilitate natural ventilation	ARUP (2012)
AE13	Details openings to limit undesired air infiltration and ex-filtration as well as to reduce convective gains	Ministry for the Environment (2008)
AE14	Provide light shelves to allow daylight to penetrate deep into a building	Ahsan (2009) and Department of Education, Northern Ireland (DENI), corp creator (1998)
AE15	Use higher window to wall area ratios to maximise solar access and ventilation	Lechner (2009), Halliday (2008)
AE16	Provide high levels of insulation in the façade and building envelope to reduce summer conductive gain and to preserve internal heat	Ahsan (2009)

Table 4-8: End user Factors passive design functionality: Façade and envelope end user factors

4.3 Passive design Performance

As stated before, this ATT is directly related to the functionality ATT. Performance is a driver that ensures the functions are performed efficiently and as required. In the literature, there are several definitions about building performance and each of them describes performance in different ways. The reason behind that is to answer the following question: how to achieve the highest rate of building performance. Many authors define performance, as cited in Ulukavak and Hensen (2006) as follows:

Kibert, et al (2001) defined that a ***“****green building is the creation and maintenance of a healthy built environment based on resource efficient and ecological principles and they emphasized that the green building covers the definitions of high performance buildings, sustainable construction, ecological design and ecologically sustainable design****”.*** As well as being comprehensive, this definition also gives a clear indicator about the relationship between green building and performance. In addition, it has referred to ecology and health, which in one way or another touches on the building user.

National Renewable Energy Laboratory (NREL, 2005) gave a description for a high performance building as *“...a high-performance building is a building that uses whole building design approach to achieve energy, economic, and environmental performance that is substantially better than standard practice. Whole-building design creates energy-efficient buildings that save money for their owners, besides produces buildings that are healthy places to live and work. It helps to preserve our natural resources and can significantly reduce a building's impact on the environment”.* There is a similarity between the contents of this description and the previous definitions except that energy has a clear place in this definition.

The *ASHRAE Green Guide* (Grumman, 2003) defines green design as *“…one that is aware of and respects nature and the natural order of things; it is a design that minimises the negative human impacts on the natural surroundings, materials, resources, and processes that prevail in nature.”* This definition clarifies the importance of reducing negative human impacts. The user also forms a central part in the performance definitions.

It is obvious that the environment is considered as the top priority, which is then followed by several areas. They can be thought of as indicators or limitations which reflect the rate of the performance in the design process. Before creating the definitions in terms of passive design, it should be indicated that the assessment tools such as BREEAM, LEED and GB-tool create the list of indicators. Each of them has several criteria in different classifications; however, their indicators can be grouped into four groups (Energy, Cost, Comfort, Environmental impacts). Hassanain (2008) classified the criteria into two main groups with sub-criteria for each of them as follows: the groups are: Technical and functional elements of performance; the sub-criteria of Technical have been classified as: Thermal comfort, Acoustical comfort, Visual comfort, Indoor air quality, and Fire safety. The sub-criteria for Functional are: Interior and exterior finish systems, Room layout and furniture quality, Support services, Efficiency of circulation and Proximity to other facilities on campus. It is obvious that there are similarities and differences between these definitions. They can be classified into three main groups: cost, comfort and environmental impacts. Energy can be matched to PD for efficiency, where the efficiency is usually centred and refers to energy and other factors. This will avoid conflict between the main factors of different definitions.

The relationships between efficiency and performance are indicated in the introduction, as it will be defined before reaching the definition of PDP.

Efficiency is an essential feature that should be considered when designing PBD. It should be considered by the designer at various levels of building. There are several definitions for efficiency. In general, it has been defined as *"the relationship between input and output or between costs and benefits in a certain system*" (LU, 2001). Another definition is for an energy efficient building: *"The energy efficiency of a building is the extent to which the energy consumption per square metre of floor area of the building measures up to established energy consumption benchmarks for that particular type of building under defined climatic conditions"*. This refers to the rate of energy consumption in each metre square of space area of the building under specific climate definitions (Sustainable energy regulation and policymaking for Africa, 2011).

Jonson comments that (2011) energy efficiency is the design that *"helps control rising energy costs, reduces environmental footprints, and increases the value and competitiveness of buildings"*. This refers to the three main aspects: economy, ecology and quality. The Centre for Sustainable Energy California (2010) defines energy as *"Energy efficiency is simply the process of doing more with less. The goal is to accomplish the same tasks and functions as before while using less energy"*. Performance in the definition refers to the design that can optimise its function under various levels of energy. Zero Carbon Hub (2009) stated that the fabric energy efficiency standard covered *"fabric U-Value, thermal bridging, air permeability, thermal mass and Metabolic (lighting, solar and appliance gains)"*. This refers to the quality and sources that can enhance the energy efficiency.

In the researcher's view performance and efficiency are two terms that are very close to each other. Efficiency is usually analysed under the umbrella of performance. This ATT is defined in terms of PD as: a set of determinants that measure PD functions performance under stated user conditions. It is important to ensure that the functions perform efficiently as specified to respond to the EUs at all times. In this work PD performance is measured through seven S-ATTs. These measures are explained in the following sections:

4.3.1 Site performance

The site factors should respond to the local conditions in terms of view, visuality and identity. Dunne et al (2011) referred to the importance of the site when designing schools in order to enhance the EU senses through concentrating on considering the immediate visual context and enhancement of the site. In terms of the views and orientation, various authors have referred to them. Padilla (2002) referred to the importance of utilizing both views and orientation. The views should be evaluated based on the surrounding buildings and on the landscape. This is in order to utilize them for building design. Long Crendon council (2009) indicated the importance of assesing a site and its effectiveness on visual focus. They referred to how the curvature of a street can help to visualise the unfolding area.

Code	End User Factors	References
BA1	Utilizing views and orientation	Padilla (2002)
BA2	Affect site on visual focus	Long Crendon council (2009)
BA3	Enhancement of site to consider identity	Dunne, Boussabaine and Stringer (2011)

Table 4-9: Passive design for Performance: Sub-Attribute: Site

4.3.2 Space

Space is one of the most important issues which should be considered regarding the PDS. This can be through considering several measurements plus PDS which can enhance the PLVT. One of the measurements is to provide suitable space for the functions and activities. Khalil and Husin (2009) point out that a building's indoor environment should satisfy users easily, which will be through providing good functionality and through being fit for the user's purpose. In terms of PD each space should be adequate with regard to PDS. Also, the importance of facilitating and responding to EU needs when they are using and occupying the building has also been referred to. The designer should create the spaces that respond to climate as well as that will be suitable for the user. Part and parcel of suitability through creating the spaces that enhance EUs' needs and demands is to design the space that creates balance between benefits from surrounding environmental sources and EU circumstances such as their ages, abilities and so on. The WBDG Productive Committee (2011) point out that the space should help the EU to practice their activities. The performance of the space should achieve the EU well-being. This is has been confirmed by both Fowler et al (2005) and the WBDG Productive Committee (2011). The latter referred to the indoor environment which can enhance human health and EU well-being. Fowler et al (2005) point out one of their questionnaire a classification is to whether the office's layout is enhancing the EU need or not; this is in one way or another space response to the

EU need. For this reason, using the natural conditions is an essential requirnemnts to enhance EU comfort. The question was *"How satisfied are you with ease of interaction with co-workers?"*" Komuro (2004) indicated flexibility, security and way finding as part and parcel of post-occupancy evaluation which is part of performance. For this reason, these indicators should be responding to the EU. They should enhance EUs and respond to their activities to help them to use the spaces without any confusion. The WBDG Productive Committee (2011) confirmed the importance of providing flexibility, social interaction and technologies to enhance EUs. Social interaction, which means EU interaction, should be considered by the designer to enable the EU to perform their function with enjoyment during their work. Hassanain (2011) points out that the building performance covers three main points, which are technical, functional and behavioural. The latter covers several points; one of them is social interaction with the building. This should be through creating the suitable space for it. Fowler et al (2005) include allowing social interaction in the classification of office performance. This should be natural in any facility to enhance interaction and activity (Cutler and Kane, 2009). Naoko Komuro (2004) and Heerwagen and Zagreus (2005) indicated the interaction between the user and the spaces and how that can enhance EU satisfaction. This could be through providing methods that enhance such as transparent glass between spaces whilst maintaining EUs' privacy. This method also shows how the space can respond to EU interaction, as well as reduce feelings of isolation. Dunne et al (2011) referred to the importance of colour selection. Montague (2007) referred to the necessity of considering special characteristics. For this reason, provide a special character for the space is selected as an essential factor that should be considered by the designeer for optimising the space performance.

Code	End User Factors	References
BB1	Durable, high quality finishes	Ministry for the Environment (2008)
BB2	Select good colour to use	Dunne et al (2011)
BB3	Passive spaces' layout to allow social interaction	Hassanain (2011), Fowler et al (2005), Cutler and Kane (2009), Naoko Komuro (2004), Heerwagen & Zagreus (2005)
BB4	Provide a special character for the space based on building type	Montague (2007)
BB5	Space layout allows for security, way finding, and flexibility of use	Komuro (2004), WBDG Productive Committee (2011)
BB6	Space layout enhances or interferes with well-being of occupants	Fowler et al (2005), WBDG Productive Committee (2011)
BB7	The adequacy of passive design space available for function/activities	Khalil and Husin (2009), WBDG Productive Committee (2011)

Table 4-10: Passive design for Performance: Sub-Attribute: Space

4.3.3 Thermal comfort

The second S-ATT is thermal comfort. This is in a simple sense how to benefit from sun to create a balance between the space and thermal comfort. Zachary et al (2010) referred to the temperature of the space and its control. Also, it has referred to the user using the temperature control buttons and if the system responds quickly. Thomas and Baird (2006) cited the importance of controlling thermal comfort as well as the importance of creating sharing between EU and designers who should appreciate the necessity for ventilation and cooling. Khalil and Husin (2009) claimed that the indoor thermal comfort can be part of EU satisfaction. The ventilation could enhance this in one way or another. The indoor thermal comfort could enhance the user's feelings or not. In the classification of performance of space (workplace), Fowler et al (2005) referred to the ability of thermal comfort to interfere with EU ability to work. Gossauer and Wagner (2007) clarified the relationship between EU and thermal comfort and how an indoor thermal environment should be created to interact with the user's space. Also, other factors such as clothing which could play a clear role on EUs' lives have been referred to.

Code	End User Factors	References
BC1	The temperature controls provide for the needs of different occupants	Zachary et al (2010), Thomas& Baird (2006)
BC2	Thermal comfort in spaces enhances or interferes with well-being of occupants	Fowler et al (2005), Gossauer and Wagner (2007)

Table 4-11: Passive design for Performance: Sub-Attribute: Thermal comfort

4.3.4 Ventilation

The third S-ATT is ventilation which plays a clear role on the PDs. Fowler et al (2005) referred to the relationship between the indoor air quality and EU satisfaction such as with regard to stuffy/stale air, cleanliness and odours. The space should adequately take advantage of air quality without any negative effects. Todd (2001) also referred to the importance of air quality as one of the performance criteria. Air movement in the space can enhance the air quality where it can refresh the air (Khalil and Husin, 2009). Fowler et al (2005) claimed that the indoor air quality also enhanced EU ability to get their job done, which means in one way or another to enhance the EU performance. This means that it is important to simplify and design the space to respond to EU needs and functions. In this criterion, using air to enhance indoor air quality enables EUs to perform their function. Milne, Morton and Kohut (2006) referred to the important task of providing internal air at a temperature that is comfortable. This is of course will be for the EUs' benefit.

Code	End User Factors	References
BD1	A comfortable internal air temperature	Milne, Morton and Kohut (2006)
BD2	The air quality in space enhances or interferes with well-being of occupants	Fowler et al (2005)
BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)	Fowler et al (2005), Todd (2001)

Table 4-12 : Passive design for Performance: Sub-Attribute: Ventilation

4.3.5 Lighting

The fourth S-ATT is lighting and how to enhance its efficiency in a space, whether artificial or natural. This is what Fowler et al (2005) said in their questionnaire classification in the light section when they wrote to what extent the EU is satisfied with the current light in their workspace. This refers to both space response to EU need and the natural source. Todd (2001) also referred to the importance of indoor light as one of the main issues that should be considered. Cutler, L.J. and R.A.

Kane (2009) referred to ensuring the adequacy of light within a space which is specifically provided for the EU. This can be through creating a space that responds to EU lighting needs. Hassanain (2011) referred to natural light as sources and space (the lobby) and how to enhance EU comfort through the outside view, which will be more desirable for them. Fowler et al (2005) referred to the fact that natural light could be more than the EU needs and give negative impacts on the use of space and could make EUs dissatisfied. This gives an indicator about the important of optimising quantity to respond to the EU. Fowler et al (2005) said that visual comfort should satisfy the EU through reducing negative impacts such as glare or contrast.

Visual comfort or day lighting should be achieved through locating the space to the outside or allocating larger window or other strategies (Khalil and Husin, 2009). All of these strategies are to harness the day lighting performance to function very well regarding the space to respond for the EU need. EU can perform the function when the quality of space lighting is very high (Fowler et al, 2005). This also is confirmed by the WBDG Productive Committee (2011). It is said that day lighting can increase the EU productivity, which is in one way or another to enhance their job. Day lighting performance can be enhanced through providing the control devices that enhance space usage easily. An atrium with curtain glass walls can quickly light the space with optimum lighting (Khalil and Husin, 2009).

Code	End User Factors	References
BE1	The adequacy of light sufficiency in spaces	Fowler et al (2005), Cutler and Kane (2009), Todd (2001)
BE2	The adequacy of natural light in spaces	Hassanain (2011), Fowler et al (2005)
BE3	The visual comfort of the lighting (e.g., glare, reflections, contrast)	Fowler et al (2005), Khalil and Husin (2009)
BE4	The lighting quality enhances or interferes with well-being of occupants	(Fowler et al (2005), WBDG Productive Committee (2011)
BE5	Atrium or rotunda control devices for optimum space comfort	Khalil and Husin (2009)

Table 4-13: Passive design for Performance: Sub-Attribute: Lighting

4.3.6 Acoustic

The fifth S-ATT which should be considered is how to optimise the sound between spaces or between inside and outside acoustics. Khalil and Husin (2009) claimed that noise pollution is one of the determinants of EU satisfaction or dissatisfaction. For this reason, designers should consider designing the spaces to care about voice privacy as well as outside noisy. Fowler et al (2005) stated that the space acoustic quality enhances the ability of the user to perform their function. The space should keep the acoustics at a limit that do not bother other EUs or lose their privacy. This gives an indicator about EU performance with regard to indoor comfort.

Code	End User Factors	References
BF1	Select insulation against noises from corridors to give space privacy	Khalil and Husin (2009)
BF2	Utilize good acoustic conditions	Fowler et al (2005)

Table 4-14: Passive design for Performance: Sub-Attribute: Acoustic

4.3.7 Adequacy of consumption and strategies

The last S-ATT is adequacy. The landscape can be efficient with regard to the design (Heerwagen & Zagreus, 2005).This includes five criteria as follows: landscape should respond to EU needs for it to be efficient. This could be through benefiting from the existing landscape or through improving it by providing trees or plants as a method to enhance occupant comfort. The Centre for the Built Environment (NA) referred to the importance of considering horizontal and vertical systems in a way to serve several EU needs. Also, this could help to move the temperature, ventilation or sun horizontally and vertically. Khalil and Husin (2009) indicated the need to provide an atrium for ease of cleaning and maintenance. One of its functions is to keep the air moving through its hall. This adequacy can lead to ensure providing natural ventilation to the space which in one way or another is a response to EUs' comfort. Finally, optimal cost through reducing the consumption of sources such as electricity, water and energy has been referred by both Zachary et al (2010) and Fowler et al (2005). Using PDS to respond to the user economically and enhance the performance of the indoor environment is a clear demand that the designer has to fulfil. Stringer (2012, p. 256) indicated that "*Response time to urgent repair issues*" is one of the issues that could affect design quality of the school.

Code	End User Factors	References
BG1	The horizontal utility systems of passive building logically configured to serve multi-user needs	Centre For the Built Environment (NA)
BG2	Utility passive design cores uniformly designed and vertically stacked	Centre For the Built Environment (NA)
BG3	Make the atrium or rotunda adequate for cleaning, maintenance, etc	Khalil and Husin (2009)
BG4	Reduce consumption of water, energy and electricity	Zachary et al (2010), Fowler et al (2005)
BG5	Response time to urgent repair issues	Stringer, Dunne and Boussabaine (2012)

Table 4-15: Passive design for Performance: Sub-Attribute: Adequacy consumption and strategies

4.4 Passive design Usability

Usability is one of the key ATTs of software design. There is a relationship between it and flexibility. The relationship is based on providing simplicity to make the designed facility usable and at the same time flexible in incorporating new EU needs as they emerge.

Each design should adapt to the surrounding area to achieve EU comfort. One of the design roles that should be considered is to create the design that is easy to use. The EU can be the owner of the space, worker, and resident and maintenance personnel. Thus the need to design for usability is one of the major issues which should be considered. Before starting the discussion in terms of passive design for usability, the meaning of usability should be understood as follows:

ISO 9241-11 (1998) defines usability as *"A product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"*. This definition is centred on three angles, each of which touches EUs directly. In terms of effectiveness, this is defined as *"Accuracy and completeness with which users achieve specified goals"*. This refers to the ability of users to complete their functions. Efficiency is defined as *"Resources expended in relation to the accuracy and completeness with which users achieve goals"* - what is the effort demanded to achieve and complete the tasks. Satisfaction is "*Freedom from discomfort and positive attitudes towards the use of the product*". This gives an indicator about the EUs' feelings when they use the design.

"The definition of usability is traditionally associated with these five usability attributes: learnability, efficiency, memorability, errors and satisfaction" (Wilson, 2009). Learnability refers to some tasks which can be done by the system. Efficiency reflects on increasing the productivity of the EU based on the efficiency of the system. The third point (memorability) refers to the ease of remembering the system after a period of time by a casual U. Errors indicates how the designer is able to reduce the predicted errors in the system, as well as how to reduce the possible errors by the EU – and if an error happens, to what extent the system can be recovered to be as it was. Finally, satisfaction is how to please the EU when they use the system.

Bevan et al (1991) defined usability as *"a function of the particular user or class of users being studied, the task they perform, and environment in which they work"*. This gives an indicator to understand the nature of the U and their function, on the one hand. On the other hand, it reflects the importance of understanding the type of the building and its components and functions in order to match EU functions with design ATTs. Eason (1988) defined usability as *"the degree to which users are able to use the system with the skills, knowledge, stereotypes and experience they can bring to bear"*. In this research this key ATT is defined as: a set of attributes that relate to operability and compliance of passive design strategies to regulation standards and user operational efficiency. This ATT is composed from three main S-ATTs which will be described as follows:

4.4.1 Operability

This S-ATT has many measurements which should be applied in a PD space. Without these measurements the EU of the space will find it hard to use. Several of the measurements have been identified by various authors.

Lund (2001) stated that the location of equipment or service should be optimum to serve the EU. It should be adjacent to the EU and easy to use. Its placement should be optimised for the EU as well as simple to comprehend. This is not limited to adjustments; also, high capacity equipment and services should be selected. All of these ATTs should be considered with regard to colour and appearance in parallel with quality.

Nylåna (2005) claimed that the EU should have an opportunity to reorganise or redesign the space. It should be legitimate for them to do this function and operate without any effort, as well as to create the suitable space with an aesthetic appearance. The suitability of the space should cope with the local regulations. The designer should also consider the size of the human form. Nylåna (2005) has referred to the importance of considering human scale. This gives a clear indicator that the designers should have a clear knowledge about the standard human scale to apply in PDS to enable the EU to operate their functions in the space. By considering the three dimensions of space to meet EUs' scale, of course, means to avoid undersizing an area, which should be coupled with the current regulations and the suitable interior space size which can attract the EU to use it. Baker and Steemers (2000) claimed that any spaces can take the advantages of the surrounding environment (passive zone). The ideal ceiling in this zone will be twice the floor ceiling height or 5.5 metres. Also, they added an instance that the atrium can increase the ceiling height. This can have a clear impact on usable floor area.

Nylåna (2005), Jensø (2011) and Brown and Cole (2009) agreed about the importance of homogeneous functions of spaces. The functions of the space can be assessed as to whether or not they are working well together. This cannot be without simplifying the design and considering the connections between the places in a way that will be clear for EUs and comprehendable to use; also, the designer should link between the aesthetics of the spaces or functions in a way that can be a magnet for the EU to use the space. Light House Sustainable Building Centre and Wimmers (2009) indicated that the ideal design should maximise usable space to the outside wall area. This will lead to operate the design function whether this fulfils EU needs optimally or not. This will facilitate the EU to carry out their functions very easily.

The floor surface of the space should be easy to walk on. Mitchell (2011) confirms the need to avoid steep floor and steps. This will make the space easier to use as well as enabling EUs with different levels of ability to operate in it. The usable space can lead to avoiding any obstacle of the space function as well as meeting Health & Safety requirements'and simple to use at the same time. Part of usability is to consider appearance such as colour or kind of material in a way that motivates the EU to use the space. This should be done without any conflicts with any local organisation regulations.

Nylåna (2005) and Brown and Cole (2009) also point out that part of usability is to provide technology and elements that are easy to use and which facilitate EU functions. This to some extent meets the aim of PDS which is to rely on environmental conditions instead of using mechanical elements, which of course, simplifies the design and elements. Simple technology can help the EU to comprehend it easily. The selected technology should also be attractive, to motivate the EU to use it.

Brown and Cole (2009) point out the importance of reducing the need to use technology or controls. Also, they, eMi2 (2006) and Barlex (2006) declared that the element should be easy to control at the same time as the indoor environment. The need to control the indoor environment is due to the various changes EUs go through in terms of their skin to various climate changes. Hampton (2011) claimed that any PBD which does not satisfy the EU by providing usable controls can be classified as a failed design.

The best kind of control is a manual one; this will be ease to use and will not demand expertise or learning. The control methods should be simple and easy for the EU to access as well as to comprehend. This will reflect on their operation when they use it, which is confirmed by Brown et al (2010) and Brown and Cole (2009), when they claimed that it was important to locate equipment controls close to the EU and for the controls to be clear to them. Simplifying the design and appearance of the controls will directly achieve the usability requirement.

Both Nylåna (2005) and Blakstad et al (2008) point out that the space area should accommodate different EU needs. This means the designer should take into account several points regarding the number of EUs. In this case, EUs can be classified into three categories, as follows: fixed number (the actual user), variable number (visitor) and rare number (maintenance/technical). The designer should provide extra areas in the space to allow for changeable or rare EUs, to help them carry out their function when they use the space. This kind of space that accommodates several kinds of EU can lead to motivate and attract EUs to use it. In addition, it will be easier for all of them to comprehend how to use it. Nylåna (2005) indicated that the spaces should be adjacent to each other. This is part and parcel of the legibility and operation of the space, which of course will enhance EU comprehension of the design when considering this adjacent space; otherwise, spreading the function can lead to confusing the EU and losing the usability of the space. Brown and Cole (2009) and Jensø (2011) referred to the ability of the EU to use features of space and elements easily as part of usability. Also, Mitchell (2011) and Jensø (2011) claimed that the area should be under the EU's power to change it, more or less. This gives the EU the freedom to operate the space as they want. Blakstad et al (2008) declared usability can be applied through avoiding non-functional and narrow space at the space level, but at the whole building level part of usability is to consider the relationship between functions and spaces. eMi2 (2006) articulated that design space should be related to physical size of equipment.

Brown et al (2010) indicated that the space should respond to the EU ecologically. When the space meets the ecological points such as light or air, this will of course reflect on EU comfort which is a kind of design attractiveness. Natural lighting will make the space more visible, which of course, is legibility. This will enhance the role of the EU to comprehend the space, and will also add touches of beauty to the space through colour appearance and renewable air. This will reflect on the EU role to operate their function simply.

Code	End User Factors	References
CA1	Optimum position of service and passive element or equipment for operability	Lund (2001).
CA2	Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	Nylåna (2005)
CA3	Group homogeneous passive functions together for efficient operability	Nylåna (2005), Jensø (2011) and Brown and Cole (2009)
CA4	Avoid slopes and steps of passive space floors	Mitchell (2011)
CA5	Incorporate passive design technologies which are easy to operate by multiple users	Nylåna (2005) and Brown and Cole (2009)
CA6	Accessible passive design controls for multiple users	Brown and Cole (2009), eMi2 (2006), Barlex (2006), Brown et al (2010)
CA7	Design passive space that is well-suited for multi-user activities and capabilities	Nylåna (2005), Blakstad et al (2008), Brown and Cole (2009), Jensø (2011), Mitchell (2011), eMi2 (2006)
CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)	Brown et al (2010)

Table 4-16: Passive design for Usability: Sub-Attribute: Operability

4.4.2 Human behaviour

The EU forms the backbone of usability as various authors confirm the need to focus on EU behaviour and aspects to harness the equipment and spaces to meet their need. Rasila, Rothe and Kerosuo (2010) said part of usability is to consider seeing, smelling, hearing, feeling and sensing of users during designing for usability. These aspects should be enhanced when designing or selecting elements or equipment to facilitate the space for EU, which of course should be recognised by the designer. This helps the EU to comprehend the space usage easily. If this is considered by the designer, it will offer indoor comfort, which is part of design attractiveness.

Hansen et al (2005) said that achieving usability is to reduce EU feelings of stress. This is, of course, to help them to operate their function without any effort. As the EU's mood can reflect on their performance the designer should recognise how to reduce the EU's stress through providing the strategies that help them to perform their function easily. Also, the colour of the space and its finish, or the building's shape can help to reduce EU stress without ignoring compliance with regulations.

Relating the EU to their culture and identity when designing the space can enhance usability (Blakstad Siri et al, 2008 and Hansen et al, 2005). Many people are obsessed with their identity which, when it is considered through designing the space, can enable them to carry out their function easily. For example, considering privacy in some societies can help the EU to operate the function easily. This will demand that the designer recognises the EU's culture and understands how it works in order to provide an appropriate space for them. The building's identity could be part of its attractiveness and lead to make EUs enthusiasm and proud of it. This will be reflected in their productivity and attendance. Many regulations of countries, such as the UK, and organisations consider culture and identity in building styles.

Mitchell (2011), Brown et al (2010), Haron and Hamad (2011) and Hansen et al (2005) declared the importance to enhance health, life safety and well-being. If all of these EUFs are achieved, it will lead to increase the rate of usability through promotion of EU comfort and other factors. Well-being is part of attractiveness design, whereas health and safety can enhance the user operability when they are using the space. For this reason, the designer should be aware of the health and safety aspects for fulfilling EU needs. At the same time, they should learn how to apply safety aspects in the design in a way that will not be difficult for the user to determine. Usually safety of the space is part of an organisation's regulations.

Code	End User Factors	References
CB1	Reduce user stress and feelings of frustration due to lack of space	Hansen et al (2005)
CB2	Consider safety, health and physical well-being needs for multiple users of passive buildings	Mitchell (2011), Brown et al (2010), Haron and Hamad (2011) and Hansen et al (2005)
CB3	Consider different sensing, smelling, hearing, feeling and seeing of users in passive space	Rasila, Rothe and Kerosuo (2010)

	design	
CB4	Consider users' cultural image, identity, life-style, psychological needs and perceptions in line with passive lighting, ventilation and thermal comfort strategies	Blakstad Siri et al (2008) and Hansen et al (2005).

Table 4-17: Passive design for Usability: Sub-Attribute: Human Behaviour

4.5 Passive design Flexibility

Any design can be flexible or complex in both form and interaction of components. Considering flexibility can add a special value to the product or the design. Where the PD should be adaptable to the environment which is the main engine to its success or not, the adaptability is not limited to the future change or to the EU needs and so on. For this reason, this terminology is coupled in PD with the concept stage.

Flexibility as a concept should be central to any design process, where it will serve the EU to perform and use the building without any effort. In addition to that, the involvement of the flexibility concept will offer comfort for the EU in the space, as well as encouraging them to be more active. So what is flexibility, and how should it be applied? These questions can be answered through analysing several definitions to understand the meaning and the main themes of flexibility. The first definition is *"specific strategies to accommodate required function, capacity, and flow changes over time"*" (Slaughter, 2001). In terms of function the author has defined that the building should be able to perform as it is required in terms of load when considering EU activities, responding to any change in the loads, conditions or volume (Slaughter, 2001). The change in the functions Slaughter (2001) referred to can be in several ways: upgrading the current function, incorporating a new function, or modification to a different function. Examples of these situations are replacing wood frames around the window glass to make it double glazed, which will lead to an increase in the performance of the space; choosing pipe lights with ventilation, which adds a new function; and the last situation is using the space in different ways, for example, to replace the living room to be an office space or the store to be a children's room. In terms of flow, the building should be able to manage the movement of people and things, on the one hand; on the other hand, it should be a managed environment and physical body in the space. To sum up, flexibility is to make a space suitable for any expected use in the future. There is another definition of flexibility: *"the ability to change and adapt a building to altered activities through its physical and administrative environment"* (Greden et al, 2005). This definition also focuses on the changeability and adaptability to the change in activities. This reflects to what extent there is an effect of EUs on the space. This definition meets the previous one at the point of changeability. This confirms the need to consider this point through several measurements, such as the ability of design to form many concepts as needed. Flexibility can be defined as *"identified potential elements that address major uncertainties in future conditions" (*Greden, 2005). This clearly refers to the design elements meeting the important functions and managing several future circumstances. The same author has defined flexible design as *"one that includes one or more option(s), or the right, but* *not the obligation, to take an action in the future*". The multiple choices of the space or element and accommodation for future change are the main two points, but it also refers to simplifying the design through avoiding restricted areas and elements. The last definition is by Moharram (1980, p.28): *"the arrangement of the space, and the tendency to change in order to suit new conditions, requirements and use"*. This definition is similar to other definitions in terms of the change and accommodation to future change, plus the use of the space. The future use refers to the EU, where the change of use will be based on their activities and their behavioural and physical needs.

It is widely accepted that the PD relies on components and their positions such as a window or roof monitor, sunspace, and so on. All of these elements are components and each of them has many sub-components. At the building level are a group of elements and the element level is a group of components. The different levels should be easy to install. For this reason, the designer should consider creating a design that will be ready to perform the installation without any obstacles. This can reflect the essential need for simplicity of the design. In PD this ATT is defined as: a set of attributes that relate the ability of PDS to be remodelled to satisfy new usage conditions. It is limited to the concepts of designing for future adaptability and flexible space. These two S-ATTs are considered to enhance space usage without major destruction of the existing space.

4.5.1 Future Adaptability

The EUFs can be classified into two routes as follows: indirect effects for flexibility and direct effects for flexibility. The indirect effectiveness can be in terms of regulation: the design should be able to be upgraded to future regulations in terms of structure, fire and safety, etc. In addition to that, there are the EUs' needs and activities, as well as changes in the number of EUs or changes in their lifestyles, to consider. All of these changes should be reflected in the design. This part is under the adaptability umbrella. However, this is not the only terminology. The other terminology (Installability, Replacability, and Coexistence) is part of it and vice versa.

The City of New York (1999) and IBEC (2008) have identified allowance of ample floor to floor height as part of future adaptability for a flexible design. This height can help future modification and adapt to any changed needs. Also, this ample height between two floors can help for easy of replacing or installing any ceiling within a suitable standard. This addition could be related to any quality or modern product. For example, if there is a demand to increase the height of a window or reduce it based on the surrounding changes or environmental changes. The position of each element should be able to cope with any standard and to be ready to accommodate it. The ample height between two floors should co-exist with any future change or adaptability without creating any dysfunction. Saari and Heikkilä (2008) referred to the long term adaptability and specified both long pan and height of the floor, stating that both of them help to remodel a building to a different type of building such as offices or residential, as referred to above.

Function is one of the most essential points of PDFL, as has been referred to by Slaughter (2001) in his classification of adaptability to changes of the function such as modification or upgrade. However, the designer should adapt the design to these sitations. Also, it should be adapted when there is a dysfunctional. Fernandez (2003) confirmed this when he pointed out that the designer should consider the risk function during future utilization. For this reason, the designer should take into account some strategies that reduce risk in dysfunctionality of future utilization. This could be through organising the components or remodelling the space. For this reason, the PD should be accommodated to deal with this, especially when adding or replacing any elements. The designer could avoid achieving this stage through eliminating some design methods. Till et al (2006) suggested avoiding tight function of the space. This is justified in that it will not need extra cost, simply demanding redistribution of the space. This gives a clear indicator about simplifying the design and considering the space area. This is one of the measurements which eliminate the fixed elements. Singh et al (1999) said that the design should be able to avoid monotony and be simple to use, redesign and so on. Remodelling and redesigning for multiple functions - all of these terminologies can be achieved through considering them at an earlier stage of the design.

Also, Blok and Herwijnen (2005) claimed that part of flexible design is keeping the other functions performing during the change of one element, which is part and parcel of avoiding future dysfunctionality. For example, when changing a window, it should not lead to interrupting other spaces or the performance of other elements. This reflects how to create neutral elements or spaces, as well as reflecting the need for extra spaces in each design. The WBDG Productive Committee (2009) and Finch (2009) referred to the simplicity of changing the element and repositioning it.

Niklas and Bengt (2009) claimed that *"Current buildings are regulated by a number of laws and guidelines"*. Any building should be able to be adapted to any future regulation. Also, this could be in terms of the extension in both sides which of course will demand the design of a structure that will coexist with the changes in regulations or future safety procedures. This will require that the designer designs a passive building in which any part of it can be easily removed or changed, as well as having the ability to add any other element or part. Till and Schneider (2006) claimed that the changing of the form should be without changing the building skeleton. This should not be limited to the building form, it could also be in the interior space. The designer should take this into account when designing a PD building. This will demand much effort where any new form should coexist with the current spaces or building structure. For example, if there is a sunspace and the trend is to remove it, the new form should not demand a lot of changes to do this. The building components should meet the flexibility standards in terms of the scale and size, quality or regulations. The interaction of the new form with the current one should be in a way that gives the possibility to benefit from the same environment.

The future EU scenario is a necessity to be kept in the designer's mind when designing PDFL. The changes could be in their numbers or behaviour. Niklas and Bengt (2009) referred to the EU activities that could be developed in the future or change, stating that the flexibility of the PD should be prepared for this situation. This is a necessary indicator which should be clarified and analysed very well. This indicator is difficult to measure, as it cannot be determined to an exact percentage. The PD should be ready to accommodate additional EU numbers, with relation to the suitable spaces' area to EU numbers and the changing of their activities, culture or work, such as when the building has been used as an office building and then changes to a residential building. The nature and behaviour of the EU of space and the level of well-being can change based on the space usage. This gives an indicator of the ability of the space to cope with EU behaviour changes.

Slaughter (2001) classified flexibility into three main criteria which are function, capacity and flow. One of the sub-criteria for the latter is changes in the environment and surrounding conditions. This could be in various ways as follows: the design should be adaptable to the climate change as well as adaptable to the installation of any element or strategies that are enhanced due to any changes in the surrounding conditions or to benefit from them. Slaughter (2001) gave the example that to replace any component of windows can fix many issues such as lighting, sound or air movement, which will necessitate that its replacement can be easily installed, e.g., when it is replaced by other components to cope with environmental or surrounding changes, whilst considering the standard to accommodate any new components to be suitable in that position.

Slaughter (2001) has referred to volume as one of the sub-criteria of capacity. The space should be designed to be flexible for changes of spatial dimensions (volume). The changing of the volume of the building is referred to as the capability of the building to accommodate addition in or on. For that, the design should be able to adapt to any contraction or extension of the space. Each addition could be to the existing space or could replace another condition. This should be provided in a way that is able to cope with the surrounding ecology. Its installation should be direct and easy, which are clear indicators in terms of the simplicity of the design. The design of the space should be adapted to the current situation and to the future situation.

Adaptations to future changes are various. Future technology is one of the good examples (Niklas & Bengt, 2009 and Finch, 2009). The rapid changes and development in technologies provide a clear challenge to the future of design flexibility. For that reason, the design should be also divided in a way that has the ability to accommodate any new technology easily. This will demand accessibility of ease to install and optimise the position. All of these requirements cannot happen without considering the standards in terms of the size such as dimensions of space or element position.

Binggeli, Corky (2003) and Milton Keynes Partnership (2006) both referred to the importance of considering circulation of a building regarding its place and how it is grouped. The first authors referred to the circulation core and how it can be used it for distribution of trees, and how this will help the rest of the design to be flexible for other use. Milton Keynes Partnership (2006) stated that services and utilities such as the central core should be easy to access. Also, the circulation element and the importance of relating it to the optimum standard size has been referred to. When any change or addition is made to the building's form the circulation should be ready to expand in both sides, vertically and horizontally. For this reason, circulation should not be limited to the same storeys; it should have the ability to cope with any extension to or shrinkage in the design.

Slaughter (2001) indicated that design adapts to the EU flow. He referred to an example which relates to increases in EU flows which is when adding two floors in a building leads to installing another staircase to enhance the EU movement. The design should be created to accommodate these changes easily. Also, the design could be changed by other EUs or become needed for other usage. The design should cope with all of these changes when increasing or decreasing the number of EUs, or the EUs' work also.

Both Vakili-Ardebili and Boussabaine (2006) point out the need to consider expectations or preference. But the need is to have a balance between the capabilities of the building. Fernandez (2003) points out that the flexibility of a building enhances the changes during design life to contain the changes in EU preference. The design and the space should have the possibilities to meet these preferences easily but without ignoring the standards of size or quality and so on. Also, the changes of their preference should cope with same circumstances and at the same time. Both Vakili-Ardebili and Boussabaine (2006) indicated the balance and the importance of building capabilities such that any change in the design or the space should be linked to the EU and vice versa.

Code	End User Factors	References
DA1	Passive building structure should be upgradable for future regulations and safety procedures	Niklas and Bengt (2009)
DA2	Design passive building to adapt for dysfunctional future utilisation	Fernandez (2003), Till et al (2006), Singh et al (1999), Blok and Herwijnen (2005), WBDG Productive Committee (2009), Finch (2009)
DA3	Allow ample floor-to-floor height for future modification	City of New York (1999) and IBEC (2008), Saari and Heikkilä (2008)
DA4	Consider the passive design that accommodates fundamental changes in user preferences	Vakili-Ardebili and Boussabaine (2006) Fernandez (2003)
DA5	Design the passive space to cope with changes in flow of users	Slaughter (2001)
DA6	Provide horizontal and vertical circulation and spaces of passive design that encompass future expansion options	Seven-Super-flexible housing
DA7	Design a passive building that responds to the increasing pressures of rapid changes in technology shifts	Niklas & Bengt (2009), Finch (2009)
DA8	Design passive space that responds to changes in spatial dimensions (volume)	Slaughter (2001)
DA9	Design passive space to respond to changes in climate conditions	Slaughter (2001)
DA10	Design passive layout based on future use scenarios	Niklas & Bengt (2009)
DA11	Select the passive building form for change without changing the skeleton	Till and Schneider (2006)

Table 4-18: Passive design for Flexibility: Sub-Attribute: Future Adaptability

4.5.2 Flexible space

The direct effect on the design flexibility can be at different levels and in different ways. In the first place, it can be through designing the space for multiple functions, which can be achieved through providing the opportunity to remodel the space. Slaughter (2001) confirmed that the spaces should be easy to reconfigure. This means that the EU needs could lead to the space needing to shrink, extend, or be redesigned. Vakili-Ardebili and Boussabaine (2006) point out that the design should be able to adapt to incorporate new functions to meet EU demands. Also, to achieve that it could be required to install a special PD or system; this should be clear and easy to do. Replacing the current function by a new function should be adapted to the current role and environmental circumstances. This demands that the designer thinks about multiple concepts of the design, as well as considering the functions and their connection together at several stages, which to some extent is to meet the point of design for multiple functions. Moharram (1980) classified the relation between flexible spaces into different criteria such as the ability to separate the spaces and combine them together. This relates to reconfiguration, as Slaughter (2001) claimed. In terms of the element, the designer should take care about the process of modification through avoiding the use of any element which can lead to interrupting the EUs' comfort or the space's function. This refers to completely changing the element or space. The designer should provide extra spaces which give the freedom to change the size of the space. Both Till (2006) and Finch (2009) refer to the need to expand the space. The separate spaces should be able to be combined into one space. Expansion can be in terms of the form of the building, or the interior spaces, without changing the form or adding onto the form.

To form the design plan as several units with the same area and shape can create flexibility to easily mix or separate spaces. Till and Schneider (2006) and Finch (2009) referred to the importance of using modular spaces and how these can play a big role in designing for flexibility. So the PD space can be configured to several forms. In addition to that, it can be combined into more than one unit. This configuration could be replaced by another based on the needs and demands of EUs. This should be done to cope with the environmental conditions. For example, reconfiguring the space on the south side which has the most exposure in PD could lead to creating a dysfunctional space which was not able to coexist with the environmental conditions. This will not be the case if the designer considers the current situation and demands.

Moharram (1980) reduces the physical separation between spaces. In any case, spaces should not be separated. However, the designer can seperat the place in case to cosider the EU privacy. Reducing the number of spaces can help to have more open spaces as well as to adapt to various environments. When the design demands some systems or new elements, the barriers will be very low. In contrast, if the physical separation is available, this will be help to access other element. These strategies can help to link the spaces and to create an easier interaction, on the one hand. On the other hand, adding other strategies can lead to adapt easily too. Saari and Heikkilä (2008) point to the importance of designing a space that is easy to subdivide. The designer in this situation should adapt the design to be flexible. Also, installation of the partition needs to be easy, considering the distance between the connection points to be suitable to standard size. As the installation should be considered, the replacement of partitions by modern ones or due to any dysfunctionality of them should also be considered. Each new partition should cope with the existing space and walls or partitions. In terms of access, each space should allow access to each other, and also have its own private route to the centre of the design. These various routes lead to the ability to change the access method to change the design to guarantee accessibility to the spaces (Moharram, 1980). The accessibility could be within or without the space. The space should have several alternatives of accessibility, which should be suitable with the standard size. In addition to that, there are different ways to access or go through spaces or creat access between the spaces that the designer could be used. These startegies can be replaced based on the function changes. The access should be able to cope with the changing of space configuration or connection.

Any spaces should have the ability to accommodate various activities which makes them multiple use, in one way or another (Finch, 2009 and Fitzgerald et al, 2009). Finch (2009) points to the ability of the place to accommodate various functions and activities. This is can be part and parcel of the replaceability as well as coexistence with other spaces or the main space. In terms of the installability this can be assessed through whether the space can accommodate the new function without demanding a huge change. Fitzgerald et al (2009) said that the alternative space should cope with the change and respond to it. This variety can give the possibility to change or add any strategies easily. According to Blok et al (2005) the designer should consider how to serve several functions at the same time, and how to provide the function which is suitable and comfortable for the EU. The design element needs to be movable (Till and Schneider, 2006). This will help to adapt the space or design and remodel it easily, and also to replace it by a new one without creating any dysfunctionality.

Code	End User Factors	References
DB1	Specify spaces for multiple use	Finch (2009), Fitzgerald et al (2009)
DB2	Use movable walls	Till and Schneider (2006)
DB3	Flexible access within and between passive spaces	Moharram (1980)
DB4	The ability to subdivide large passive design spaces	Saari and Heikkilä (2008)
DB5	Use modular passive space planning strategies	Till, and Schneider (2006), Tatjana (2006), Finch (2009)
DB6	Minimise partitions between passive spaces to control lighting, ventilation and thermal comfort	Moharram 91980)
DB7	Design passive space to incorporate completely new functions	Slaughter (2001), Vakili-Ardebili and Boussabaine (2006)

Table 4-19: Passive design for Flexibility: Sub-Attribute: Flexible space.

4.6 Passive Design Reliability

Reliability and durability are two terms which share some common characteristics. Each element or material which will be suggested by the designer should be selected of high quality which will reflect on the function's performance and will avoid its possible dysfunctionality. This also indicates the longevity in one way or another. It is defined in PD as: a set of determinants that relate to the capability of passive design functions to maintain their level of performance under user stated conditions within the design service life period. It is limited to the concepts of designing for durability, material reliability and resilience. These three S-ATTs are considered to enhance design reliability.

4.6.1 Durability

This S-ATT has many measurements which should be taken into account when designing PDR. This measurement should be applied with consideration of the three S-ATTs, which are adaptability, quality and dysfunctional acceptance. One of the most important indicators is longevity, which is one of the most important features of reliability. ABCB (2006) stated that the components of the design should be fit for use during the design's life. The importance of considering design components to be easy to access and economical to repair and replace during the design life has also been referred to. As has been referred to in the introduction, longevity refers to consideration of accessibility, which in the researcher's view is to check that the element components are reliable with the changeable environmental conditions.

The elements of the PD should be selected to be of high quality in order to face the various changes. This will ensure the design will be more reliable longer than expected from the EU. The designer should consider the longevity of both element and space (Bijen, 2003; Mital et al, 2007; U.S. Department of Housing and Urban Development, 2002; Davies and Wyatt, 2005; and Carlsson et al, 2005). Part of durability is to consider service life during design life through accomplishing the quality of both elements and components (Balaras et al, 2005: Carlsson et al, 2005; and Wright and Frohnsdorff, 1985). Balaras et al (2005) indicated that design space should be taken into account together with its ability to change to better conditions. ABCB (2006) claimed that the design should be resistant to any conditions. At the same time, its type should be capable of adapting to any malfunction to enable the PD to recover its function without any dysfunctionality of the whole building's elements. The importance of element selection is not limited to selection of the elements but also to selection of its small competents such as joining points. Also ABCD (2006) stated that joining the elements together should be considered by the designer. The designer can play a clear role at this stage through two routes as follows: through reducing joining points on the building, which will make them more reliable and easy to check as well as reduce the possibility of any dysfunctionality occurring. The second route is that if the design imperative includes various joining points, it should ensure that the PD elements are of high quality. This will enable the building in general and the element specifically to face the changes and the future risks which could lead to damage to or malfunction of its function. Each element's possible dysfunctionality should be limited so that it does not affect any other element.

The changes to the environmental conditions are various and could be from wind, temperature or sun. The designer should deal with these changes in a way that avoids over quantity to avoid the design having any dysfunctionality. The design of the building also should respond to various environmental agents and longevity. The designer should take the responsibility to investigate these issues. ABCB (2006) and PERD (1997) confirmed that the service conditions should be resistant to rainfall, humidity, heavy snow, flash flooding and intense sunshine, temperature and wind flow. For that, the elements which could be exposed to these challenges, such as the roof of PD or façade, should be able to accommodate the necessary changes.

Mital et al (2007) referred to the importance of protecting the sensitive points from accidental change, as well as to avoid stress points and sharp corners. The protection of the points can be part of the quality. These points should be considered when designing the building and, in one way or another, refer to simplification of the design. Hence, the complexity of the building can lead to create a lot of the problems regarding reliability and other EUFs. Simplifying the design through avoiding stress points can enable any dysfunctionality to be easily rectified. In addition, it could help to provide temporary solutions.

Davies and Wyatt (2005) agreed about the importance to ensure both space and elements are serviceable; at the same time, they should reflect EU needs and future challenges. The designer could achieve this serviceability through providing high quality elements. This will enable the elements to respond to the changes which could be issued by the EU such as accidental or environmental or way of life or whatever it will be. The serviceable spaces should be easy to maintain and check. This will enhance both passive space and elements to match EU needs.

Part of durability is to provide services such as drainage to reduce accumulation of moisture, as well as to use devices the can shed the water away from the wall (PERD, 1997). This will be achieved through considering the standardisation and quality of the elements. Exposure of an element should not create another dysfunctionality when it is broken or cannot perform its function. Being easy to fix means that it is easy to refurbish its function. The following table lists the measurements of passive design for reliability.

Code	End User Factors	References
EA1	Ensure the passive performance of space or element remains serviceable	Davies and Wyatt (2005)
EA2	Provide optimum drainage and venting to minimise accumulation of moisture	PERD (1997)
EA3	Design passive service life to match user needs	Davies and Wyatt (2005)
EA4	Select components that are resistant to environmental agents	ABCB (2006)
EA5	Compatibility in joining lighting, ventilation and thermal comfort elements together	ABCB (2006)

EA6	Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation	ABCD (2006) and PERD (1997)
EA7	Protect sensitive passive elements from accidental change	Mital et al (2007)

Table 4-20: Passive design for Reliability: Sub-Attribute: Durability

4.6.2 Material Reliability

One of the most important building aspects which should be considered during design of PDR is material selection. ABCB (2006) claimed that the design should respond to different environmental agents, and that the rate of expansion and contraction of materials should be considered when selecting the appropriate ones to use. This means that considering high quality material is one of the most essential parts. This is closely linked to the responses to different environmental agents, whether in the summer or winter. The material should be suitable for various environmental changes. When the material expands or contracts, the PD should perform its function easily without any interruption until the material is restored to its normal size. This could be achieved through the design by providing expansion joints within the materials to cope with the changes. Also, PERD (1997) confirmed the importance of considering the changeability of material size which may lead to cracks. For this reason, ABCB (2006) focused on the importance of using high quality material and natural material. The designer should also consider the material composition and properties to ensure that it can handle any emergency changes. This could lead to reduced concern regarding the restoration which will rarely be done with high quality materials.

Building joint seals and standardisations are part of quality. Many authors, including Wright and Frohonsdorff (1985) refer to the importance of considering building joint seals in PDR. For this reason, standardisation standard material should be used for both the material and element, to ensure their reliability and durability (Wright and Frohnsdorff, 1985; ABCB, 2006; Balcomb, 1992; NAHB Research Center, 2002; and Mital et al, 2007). Standardisation and seals are able to help the designer to handle the issues relating to changes. This will lead to maintaining the functions of the points or easily restoring them, especially when they are selected based on the standardisation. As a result of that, the material is at the centre of S-Atts of PDR.

Code	End User Factors	References
EB1	Consider passive building joint seals to resist infiltration of moisture or deleterious materials	Wright and Frohnsdorff (1985)
EB2	Use high quality material with long service life to handle passive functions	ABCB (2006)
EB3	Consider the rate of expansion / contraction of material of passive design strategies	ABCB (2006)
EB4	Use standardisation of passive design elements and materials	Wright and Frohnsdorff (1985), ABCB (2006), Balcomb (1992), NAHB Research Center (2002), Mital et al (2007).

Table 4-21: Passive design for Reliability: Sub-Attribute: Material Reliability

4.6.3 Resilience

In terms of resilience, it can be to climate change and EU behaviour. PERD (1997) indicated the various changes which could happen in the building, e.g., there could be a defective or broken beam in any part of the building. Therefore, quality is a necessary part that should be considered to accommodate and handle these changes. Also, the design element should have the capability to restore the function if it is lost as a result of any malfunction. Resilience could be classified into two routes: to restore the whole building functions or some part of them. This does not mean that the whole building's performance is dysfunctional. Balcomb (1992) and Mital et al (2007) referred to the importance of adapting to climate change or changing environmental conditions. ABCB (2006) claimed that user behaviour during service life should be taken into account, such as heavy use or accidental impact. The only way to meet that is to provide the element or material that is able to cope with the user behaviour whatever their age and ability. Also, this element or material - especially the element which always be used by the EU should be easy to refurbish in case of the possibility of exposure to any damage or defect. This will lead to keep the EU using them without any malfunction to space function or their activities. The following table shows the measurements which can help the designer to create the space that is more reliable for aspects relating to adaptability.

Code	End User Factors	References
EC1	Specify passive space strategies for user behaviour usage (such as heavy use, accidental impact and interior humidity)	ABCB (2006)
EC2	Passive building fabric should be adaptable to cyclic change	PERD (1997), Balcomb (1992), Mital et al (2007)

Table 4-22: Passive design for Reliability: Sub-Attribute: Resilience

4.7 Passive Design Maintainability

Maintainability is an ATT that interacts with the reliability measure; for example, selecting material that should be reliable and so reduce the need for maintenance. Also, passive building functions should be reliable in their operations under all assumed design conditions.

Maintainability or ease of maintenance is one of the most important issues which should be considered during the PD process. It will enhance the function in case any dysfunctionality occurs so that it can be fixed quickly and easily. For this purpose, before starting to explain how this can be considered in PD, various angles need to be discussed. For this reason, the definition of ease of maintainance needs to be understood. In fact, there are various definitions which have been referred to by several authors. Some of them share some aspects. According to BIS (1993 as cited by Das et al 2010, p.1043), maintainability is defined as *"the ability of an item, under conditions of use, to be retained in or restored to a state in which it can perform its required functions, when maintenance is performed under stated conditions and using prescribed procedures and resources"*. Maintainability is paired with other ATTs and this is obvious in the definition where it has referred to the function and performance at the same time. Restoring the function of the element or design space means guaranteeing the longevity of the function. This is achieved through relating elements' expected defects to future maintenance. In addition to that, another definition looks to ease of maintenance for several routes, some of them the same or similar to the routes in the previous definition.

Dunston et al (1999, p.56*)* defined maintainability as *"the design characteristics which incorporate function, accessibility, reliability and ease of servicing and repair into all active and passive system components that maximises costs, and maximises benefits of the expected life cycle of a facility"*. This states that the design should be easy to access; more reliable in order to reduce the cost of maintenance; and that the building and elements should be more durable. This matches the previous definition with the concept of considering expected future maintenance, which reflects the importance of simplifying the design to avoid using complex or low quality materials. Accessibility forms another route that should be considered to access the element or space. This forms the differences between this definition and the other one. Its importance will be clarified in the discussion of the PDM.

Hasselbring (2006) defined maintainability as *"The ability to undergo repairs and modifications"*. There is a definition that maintainability *"encompasses corrective, preventive as well as perfective or adaptive maintenance"*. It does not immediately refer to the operation of the system, but to its design. Both definitions refer to the design of maintenance, and to what extent design can help to perform the maintenance of the building.

Stephen et al (2011) defined maintainability as *"The relative ease and economy of time and resources with which an item can be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair"*. This definition looks at ease to maintain.

It has also been referred to as *"A characteristic of design and installation, expressed as the probability that an item will be retained or restored to a specified condition within a given period of time, when maintenance is performed in accordance with prescribed procedures and resources"*. The last two definitions look at usability and ease of maintenance together.

Maintenance Trebling			
Movement		Operation	
Trebling name	Description	Trebling name	Description
Human move	move along path	Get	grasp and hold something
Carry	carry something and move along path	Position	position a tool or object to the goal
pose	adjust posture to do action	Hold	human keeps his posture, or keeps object still
		Place	place tool or object
		Release_Resume	release tool or object and resume default posture
		Use – tool	use tool to operate on object
		Operate	operate such as: push, pull etc

Table 4-23: Maintenance Trebling (Hao et al, 2006) Definition of maintenance trebling is that *"information of human movement and motion is described in the maintenance simulation"* (Hui, 2004, p.1).

From these definitions, it could be concluded that ease of maintenance is centred on three factors. First of all, standardisation refers to applying the design and using the elements based on standardisation. In the second place, it refers to the materials and the importance of longevity and quality. Finally, accessibility and cleaning refers to ease of maintenance and access to the defective area. As has been discussed within the previous definitions, simplifying the design means avoiding complexity in order to help the maintenance personnel perform their work. The definition of PDM in the proposed model is: a set of determinants that relate to the ease of inspecting, maintaining and modifying design to satisfy continuous evolving user needs. There is a clear interoperability between maintainability and passive design. Wulfinghoff (1999) points out that the maintainability of PD should be minimal; based on that the design will be ideal. In terms of being combined with other mechanical elements, it should be designed for maintainability and also easy of maintenance.

Maintainability will be achieved through several measurements and features which should be considered thoroughout the design process. The measurements are entered under three main factors. For this research, the measurements have been considered, as well as how to apply them in the design process. In addition to that, how to facilitate the design to support both user and personnel in inspecting and performing building maintenance has been considered. Also, the EU can be part of an inspection, on the one hand. On the other hand, the EU can cause the need for maintainability through their misuse of an element.

Maintainability should also be considered in different ways through the design process. Identification of the defects in the building and components is one of the measurements which should be taken into account and how to facilitate them for EUs. This can start from identification of the expected area and elements which will demand maintenance in the future.

The expected area is different, such as wet area basement. In terms of the elements, they are also various but in general include roof elements and façade elements or façade in general. For this reason, this section will cover the demands of considering maintainability for elements and space based on EU needs and ability. The EU plays a clear role in any maintenance, which has been confirmed by Hao et al (2006). It is said that maintenance describes the action and human features, which is referred to in Table 4-18. The EU behaviours are various depending on their attitude or place of using the space. The behaviour could be movement or could be carrying out something which could cause any damage; therefore, the designer should take them into account as a centre of the design.

4.7.1 Standardisation

In terms of standardisation, provision of lighting and ventilation are among the main measurements which should be taken into account through the design process and concept, whereby visibility for the designer and personnel plays a big role in diagnosing a defect at the early stage and supporting the personnel to change any PDS dysfunctionality whether in terms of the space or element with high visibility. Clear vision also helps to keep other functions safe. Finally, consider eye vision can lead to ease testing the element and the pace. Also, creating the surrounding area to be functional for the personnel through providing ventilation will reflect on their performance too. The Office of Health, Safety and Security (2001) confirmed that there is a need to provide a movable light to support the visual tasks of personnel. In terms of PD, it is important to rely on natural lighting and spread it into the majority of the spaces, which can lead to achieving this point, as well as natural ventilation too. One of the sub-factors is the installation of the element or material. The designer should simplify the design as far as possible. The Energy Saving Trust (2006) point out that the workmen should understand how to install the element, and whether the element needs to be installed or changed. Also, the designer can enhance the personnel role. Then, the size of the element should be ensured; for example, if the size of the duct or stack vent or sun pipe is not very well considered, this will have an effect on the amount of ventilation or day lighting. Installation can be with various elements. Passive stack ventilation is a good example. The measurement of installation of passive stack ventilation is as follows: when installing passive stack ventilation the installer should try to make it as vertical as possible, avoiding more than two bends to ensure air flows easily; both inlet and outlet of the duct should be securely repaired to avoid disassembly (Energy Saving Trust, 2006). This can help to diagnose and inspect the element. Also, simplifying the method of installation will reflect on the changed element better than incorporating many bends which, when installing or changing any one could create another dysfunctionality. If there are no bends, the element will be able to be easily changed, even for diagnoses or to test the success of maintenance. This reflects how the design simplicity is a clear demand.

Dunston and Williamson (1999) confirmed that there is a need to simplify the design. This is also confirmed by both Ramly et al (2006) and Al-Hammad et al (1997), who concentrated on the need to avoid irregular shapes in the design, or to simplify the design in other ways. This can cover several issues in terms of the space, or joining the design elements or functions, where simplicity can enhance diagnosis of the expected maintenance area easily as well as to allow change or modification of the dysfunctional element or space and consider the other element or function at the same time. The complexity of the design can lead to disabling other functions at the same time. The PDS should avoid the conflict between them; this will help to easily fix the problem at the same time as testing it. It can be said that it is the backbone and the first point of ease of maintenance (Griffith University, 2011). The design should be free of sharp angles and edges for easy access in order protect maintenance personnel's eyes. The sharp corner can be a barrier during connection of the elements or roof. Even if the connection is handled well, the sharp corner can cause some difficulties during checking, changeing and testing. Griffith University (2011) stated that the designs of the building can prevent hazardous areas such as confined spaces or roof surfaces. This fact is referred to in one way or another as simplicity, which has been stated above. Haiquan et al (2011) and Wani et al (1999) stressed the importance of focusing on assembly of the elements and their fitting together. Making something easy to connect or assemble can be achieved through selection of simple elements which can perform the same function, which can help the workmen to check the element without creating damage to the whole building function. Also, NASA (2008) indicated the importance of joining and fitting the elements together. Mohammed and Hassanain (2010) and Crow (2002) pointed out the importance of design for assembly and minimising the joining points. This can also help make the item easy to change because the joining points are few. The workmen can help to test this easily and fix the problem quickly. This can help also if the problem requires the disabling of other functions, as it will not take a long time. As there is a necessity to consider the adjustment, it must also be easy to adjust. Northumberland National Park (2006) indicated that using modern adjustable brackets can lead to minimising the risk and problem of maintenance. This confirms the need to simplify the design to accommodate any adjustment, or new technology.

ARIS (1995) and Chew et al (2004) referred to the importance of easy removal or replacement of the elements or certain design components. Ease of removal and replacement means ease to change, which needs to be considered in order to support the personnel to do their job well. The ease of removal, as referred to above, will demand that the element is accessible for ease of diagnosis and testing. Also, Parsloe (1992) and Ramly et al (2006) both confirmed the importance of simplifying the design detail and avoiding complexity. They also referred to ensuring design detailing to facilitate maintenance by the EU who will inspect elements or the personnel who will fix the defects. Poor detailing can be an obstacle for the personnel when they change any elements or material. Also, it could be difficult to diagnose or test the maintenance. This could also affect the quality of the workmen's performance. De Silva et al (2004) claimed that one of the methods to achieve standardisation of points in a building is the use of components such as doors, windows, etc, in a standard size. This reduces the complexity of the design as well as achieving the standardisation of the building. Also, these types of elements could be familiar to personnel in terms of diagnoses or tests and will maintain the size location. NASA (2008) confirmed the importance of removing or replacing any component or element without the need of damaging the whole system or design, or other components. In the PD process the components of the façade or the roof should be easy to remove, change, and test and able to be assembled as products. Therefore, any part can be checked without causing dysfunctionality in other functions; for example, changing the glass of the façade whilst maintaining the other building functions. Another example is changing the sun pipe without needing to separate the power. This gives a clear indicator that, when designing the PD, the PDS should not cross with the grid of electricity or other drainage. This reflects the importance of simple design, as well as joining elements together, so that connections can only go together in one way, and so will be easy to change or diagnose. In contrast if connections can go more than one way, this could create dysfunctionality with other elements or space. This is called design interfaces, which means designing the spaces and components to avoid the possibility of joints overlapping in multiple ways. The importance of the ability to design for interchangeability refers to the ability to install elements without major readjustment. This is one of the measurements for ease of installation of the elements through the maintenance process.

Code	End User Factors	References
FA1	Provide lighting and ventilation in expected maintenance areas	The Office of Health, Safety and Security (2001), Griffith University (2011)
FA2	Simplify interface of passive design elements and building façade	NASA (2008), Haiquan et al (2011), Wani et al (1999), Mohammed and Hassanain (2010), Crow (2002)
FA3	Specify simple shape of both building form and space of passive design	De Silva et al (2004)
FA4	Utilize non-destructive disassembly passive design strategies	NASA (2008)
FA5	Eliminate poor detailing of passive design space or element	Ramly et al (2006), Parsloe (1992)
FA6	Design for ease to remove or replace lighting, ventilation and thermal comfort elements	ARIS (1995), Chew et al (2004) and NASA (2008)
FA7	Design for ease to adjust lighting, ventilation and thermal comfort physical element features	Authority Northumberland National Park (2006)
FA8	Design for ease of installing lighting, ventilation and thermal comfort element or material	NASA (2008), Energy Saving Trust (2006)
FA9	Provide passive design strategies that minimise the time for maintenance	NASA (2008). DESIGN FOR MAINTAINABILITY

Table 4-24: Standardisation Measurements

4.7.2 Material

The second main S-ATT is the material of the design. The material should respond to changes in climate to give indicators for longevity and durability. Wood (2005), De Silva et al (2004) and Dunston et al (1999) point out the importance of considering durable materials when designing buildings. Also, they refer to the importance of considering long-term operation of materials, and choosing durable material, even though that demands more cost. It leads to increasing the cost at the early stages, but reduces the cost of maintenance in the long term. In addition, the longevity of some materials will be less than that of other materials in other parts of the building, such as in the façade area. For this reason, high quality material should be selected in the spaces which directly face the climate. The longevity and durability can reduce the need for changing, testing or diagnosis because quality can play a big role in that. Also, they will reduce the possibility of dysfunctionality or disabling of another function or element. Parsloe (1992) and De Silva (2004) looked at the material in terms of the maintenance and its ability to incorporate with each other. NASA (2008) indicated that the material and design components should be chosen based on availability. This will be for ease of change and to avoid the possibility of delay. In terms of the design, this target can be achieved through minimising the use of unique materials. Also, NASA (2008) points out that there is a need to mitigate and reduce the complexity of any design process through using a common part of any process, as well as using the elements and components for multiple functions. This common material can help diagnoses and tests, which will be easier for any personnel. This will maintain the other functions through reducing the maintainance time. NASA (2008) confirmed the importance of the location of the material and avoiding unsustainable positions. The position should be clear and direct for the EU to inspect or check as well as to change the material. Some strict positioning could lead to incapacitating other functions. Again, the simplicity of the design can be the centre of all of that. Where the equation for the position of the material is clear and simple, the maintenance will be easier, and vice versa.

Code	End User Factors	References
FB1	Minimise use of unique materials of passive design strategies	Parsloe (1992), De Silva (2004), NASA (2008)
FB2	Locate lighting, ventilation and thermal comfort materials for operability to minimise degradation	NASA (2008)
FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity	Wood (2005), De Silva et al (2004), Dunston et al (1999)

Table 4-25: Material

4.7.3 Accessibility

The last S-ATT is accessibility; which is the most important factor, as without it both of the previous factors cannot work and perform very well. Each element should be easy to access for maintainance, as has been referred to by several authors (NASA, 2008 and Crow, 2002). Accessibility can be in terms of the diagnoses, testing or changing. Without any access, the aspect of maintenance cannot be achieved. Accessibility can eliminate the possibility of dysfunctionality of other elements. Different authors confirmed its importance in terms of equipment, facilities and components to achieve maintainability in the building. Lin (2010) points out the importance of considering maintainability from the early design stages as well as diagnostic, access/instrumentation. Diagnostic refers to accessibility in terms of routes, visibility or ease of access to the equipment. This confirms this theme as the most important of the three main factors. Cleaning and maintenance are usually coupled together. When EUs inspect or clean any expected maintenance area or interior design element then they can discover the dysfunctionality of them. Also this can mean they are easy to access or diagnose or change any elements. For this reason, areas should be easy to access to investigate. The Energy Saving Trust (2006) point out that usually PD requires little maintenance in normal circumstances. As the roof terminal needs to be checked periodically, access should be provided to it. The outside of the building can have critical elements, such as the roof which should be easy access, inspect, test or change. In addition, the grills, such as those in the kitchen, should be easy to clean and there should be no restriction of the air flow.

Chew et al (2004) claimed that providing adequate space is necessary for repair, change or diagnoses. The personnel or user needs to be able to perform their task easily (Solana et al, 2005). Cleaning and maintenance can be difficult or easy tasks; this will be based on the degree of the simplicity of the design process. NASA (2008) refers to the importance of considering opening size of place maintaince expected to be easy for personnel to change, test, and diagnose when they practice their work. Also, optimal size opening can help them to practice maintenance without creating another dysfunctionality. In contrast, the tight space will be uncomfortable; this will reflect on their performance too. It is necessary to help personnel to perform their functions within a comfortable space. If the EU is in a tight space, they cannot use it to live or to inspect the defects of components or space.

NASA (2008) referred to the need to avoid any obstacles on the route when providing any components. For this reason, the designer should take into account the dimensions of the space; and corridors should be considered with regard to the need to move materials and elements through them. Otherwise, it will be hard to do anything except to create many problems and stop the performance of the building and EU in managing it. Providing wide corridors can also help to test and replace the elements if they are not suitable and vice versa. Finally, during the design stages, starting from the concept to the final drawing, maintainability should be considered, as well as any factors which can interrupt the design for maintainability, such as structure.

Code	End User Factors	References
FC1	The cleanliness and maintenance of passive spaces enhances or interferes with well-being of occupants	Solana et al (2005)
FC2	The interior of the passive building is designed to be easy to clean and maintain	NASA (2008), Chew et al (2004)
FC3	Access routes of passive space for transport of maintenance materials	NASA (2008,13-5)
FC4	Critical lighting, ventilation and thermal comfort element should be visible for inspection	Lin (2010)
FC5	All elements of the external passive building shell should be easy to access for maintenance and cleaning	Energy Saving Trust (2006), Solana et al (2005)
FC6	Optimise sizes for passive design openings for workmanship access	NASA (2008)
FC7	Locate passive design elements where they are accessible for maintenance and repair	NASA (2008), Crow (2002)

Table 4-26: Accessibility Measurements

Issues learned from the literature	Argumentations	Research gaps	Research Questions
Are there EUFs that could help the designer to meet EU needs during PDF?	As per the literature review discussed in this chapter, the EUFs be classified in different ways.	There is a need to invistigate the EUFs of PDF.	What are the EUFs of PDF?
Are there EUFs that could help the designer to meet EU needs during PDP?	As per the literature review discussed in this chapter, the EUFs be classified in different ways.	There is a need to invistigate the EUFs of PDP.	What are the EUFs of PDP?
Are there EUFs that could help the designer to meet EU needs during PDU?	As per the literature review discussed in this chapter, the EUFs be classified in different ways.	There is a need to invistigate the EUFs of PDU.	What are the EUFs of PDU?
Are there EUFs that could help the designer to meet EU needs during PDFL?	As per the literature review discussed in this chapter, the EUFs be classified in different ways.	There is a need to invistigate the EUFs of PDFL.	What are the EUFs of PDFL?

Are there EUFs that could help the designer to meet EU needs during PDR?	As per the literature review discussed in this chapter, the EUFs be classified in different ways.	There is a need to invistigate the EUFs of PDR.	What are the EUFs of PDR?
Are there EUFs that could help the designer to meet EU needs during PDM?	As per the literature review discussed in this chapter, the EUFs be classified in different ways.	There is a need to invistigate the EUFs of PDM.	What are the EUFs of PDM?

Table 4-27: The issues learned from the literature

4.8 Summary of this chapter

The functioning of passive buildings is based on a few physical rules that are interoperable. These rules have to work together in a homogenous way. The performance of these functions has to be considered by the designer based on EU needs. There are various researchers who are interested in performance assessment. However, considering EU needs was not part of their various assessment tools, even though some of these tools included occupant comfort. The six ATTs can help the architects to meet the majority of EU needs in terms of functionality, performance, usability, flexibility, reliability and maintainability. EU needs are the core of each of these ATTs. The designer needs to consider and integrate the EUFs during the design process to maximise the fulfilment of user needs. In the researcher's opinion, the measures listed at the end of each S-ATT provide draft guidance for the designer to ensure that the building fulfils its PDF and responds to EU needs. The list considers EU aspirations from both physical and psychological aspects. The question one might ask is what model could combine these ATTs? In addition to that, what is the process that could help the designer to meet EU needs in different ATTs before posting the design? This will be discussed in the following chapter.

Chapter Five: User Centered Passive Building Design Model

5.1 Introduction

In the previous chapters, the researcher reviewed the necessity of creating such a method that could help designers to meet EU needs. This has been proven through the various citations which were introduced in the first chapter. However, finding from the UCD theory which is applied in the IT industry was not enough to investigate the EU demands. For this reason the researcher started investigating the method that could maximise meeting EU needs. This was the reason to investigate the EUs' aspirations regarding various ATTs. After this review of meeting EU needs, it became imperative to propose a model that would lead to bridging the gap between PD and EU needs; and, furthermore, to investigate a process that could help the designer to confirm integration of EU needs at various levels. This is addressed by the researcher in this chapter.

5.2 Components of the Model

The proposed User Centered Passive Building Design Model is illustrated in Fig.:2. As shown in the figure the model consists of several fully integrated design strategies. The process of user centred design is an approach that ensures that all four layers of the model interact with each other in a way that delivers highly performing building assets that satisfy all end-users aspirations. This conceptual model consists of three passive design strategies, i.e., lighting, ventilation and heating, as the core on which other design strategies are based as illustrated in the fig. 2. Passive design solutions are then evaluated for their effectiveness in fulfilling users' needs according to the steps shown in the figure. The assessment is based on the design constructs of functionality, performance, usability, flexibility, reliability and maintainability. The feedback from the life cycle of the design process is also included to capture essential knowledge for developing future designs. Hopefully by following this process systematically knowledge about U needs is acquired and learning from past experiences is feedback into design. Before the researchers embark on a detailed analysis of the proposed user centred passive building design model, the researchers would like to draw the attention to the definition of passive design that is adopted in this work. This research defines passive user centred design as "a passive design approach that places both user and passive design strategies at the centre of the design process to focus architects' mind on end users' need through the planning, design, development and operation of building assets". The concepts in the definition will be the foundation on which user centred passive building design model is conceived, developed and reported in this chapter. The following sections will explain the components of the model shown in Fig 2:

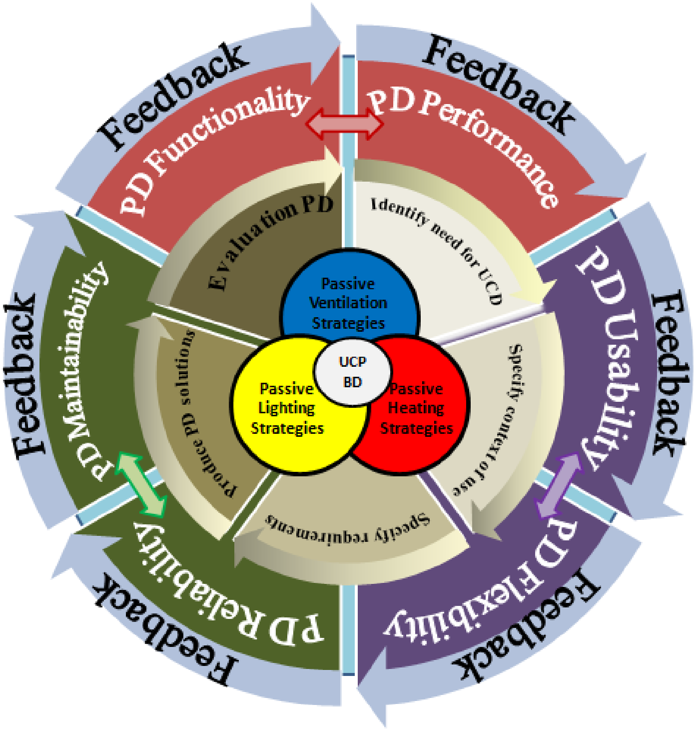


Figure 5:1 User Centred Passive Building Design model

5.3 Core Passive Strategies

PD is an approach that has emerged to reduce environmental impact by using any non-mechanical means for heating and cooling buildings. This will be achieved through design strategies that make use of natural environment sources in a way that enhances the three dimensions of passive design. That is to say, lighting, ventilation and heating, as shown in Figure 5:2. It is theorised that following these design strategies will lead to reductions in the consumption of energy and production of environmental pollution. The passive design strategies spring out from the three dimensions of passive design, as shown in Figure 5:2.

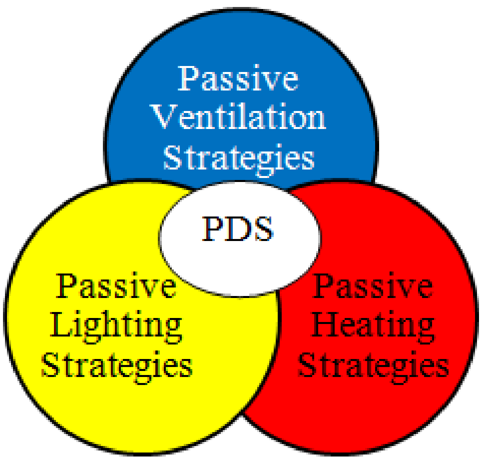


Figure 5:2: Passive Design Strategies' Dimensions

Passive design is defined as *"an approach to building design that uses the building architecture to minimise energy consumption and improve thermal comfort. The ultimate vision of passive design is to fully eliminate requirements for active mechanical systems"* (Vancouver, 2008. p.3). Feist (2007) defines passive design as *"a Passive House is a building in which thermal comfort can be guaranteed by post-heating or post cooling the fresh-air mass flow required for a good indoor air quality".* Even though the previous definitions refer to the indoor air quality and thermal comfort, these measures are considered to be part of the end user requirements. However, the definitions do not consider all the end user needs as envisaged in ISO standards. The definitions of the three dimensions of passive design that are adopted in this work are as follows:

5.3.1 Passive Ventilation

This dimension concentrates on benefiting from natural ventilation through maximising building design to reduce use of air conditioning. Passive ventilation (PV) has various definitions as represented by several authors. PV is defined as *"Using the convective nature of warm air and the ability to control windows and vents as the environment changes to control air floor in a structure*" (Chief Architect, 2010). This definition refers to two ventilation strategies, which are windows and vents, and concentrates on the importance of controlling ventilation. Control is one of determinants which should be able to be used by the user even if it is not clearly referred to. However, some other definitions refer to the user, such as the following: PV is *"The introduction and/or removal of air that used both convective air flows resulting from the tendency of warm air to rise and cool air to sink, and takes advantage of prevailing winds. Many passive ventilation systems rely on building users to control their operation".* This definition considers the users as well as the prevailing winds to be part of the PV, which means the orientation and the user preference. Also, this definition highlights the importance of ventilation controls being placed in a clear condition, as well as the importance of the ventilation input and output processes (American Hotel & Lodging Association, 2010). This author shows the significance of considering the user in passive building design as well as the importance of orientation for optimum ventilation. Operation control is indicated as an important function for the end user. This source has defined natural ventilation as *"The process of supplying and removing air through an indoor space by natural means"* (American Hotel & Lodging Association, 2010). This definition refers to the process of operation only and the user is not mentioned, but it could indicate that the designer through indoor space which is to relate passive design strategies with design space. PV is described as *"Refers to buildings that use very low amounts of energy to heat the space"* (RAIC, 2008). This means reducing consumption of energy by using nature to warm the space. This definition refers to the consumption of energy as well as the purpose and result of using the function. Also, the author defined natural stack ventilation as *"Natural ventilation achieved by allowing warm air to rise and vent out of a building through upper openings which will draw fresh cool air in through openings on the lower levels".* This definition refers to the upper openings and their enhancement to move air from the space to outside. The last definition is *"The provision of ventilation using non-mechanical means"* (HCA, 2008-2010). This means to supply the space with ventilation through opening windows or through traditional approaches such as courtyards or wind towers.

5.3.2 Passive Lighting

PL has been defined in different ways but the main concept is about the benefit from the natural lighting to minimise use of energy. The initial definition of this concept is *"day lighting has often been recognized as a useful source of energy savings and visual comforts in buildings"* (Li and Tsang, 2008). This definition has considered day lighting as a balance between EU demand and energy needs. PL is characterised as *"Design practice that uses sunlight to reduce or removed the need for electric lighting. Elements to consider include orientation and placement of windows, light shafts/tubes, skylights, clerestory windows, reflective surfaces, and interior passage of light between rooms"* (Chief Architect, 2010). These definitions have specified PL functions and strategies. Nevertheless, user needs did not appear in them. Another definition of PL is represented as *"Method of illuminating building interiors with natural light"* (RAIC, 2008). This simple definition also refers to the function and the purpose of day lighting. It suggests that day lighting be defined as *"A method of illuminating building interiors with natural light and minimising the use of artificial lighting. Common day lighting strategies include the proper orientation and placement of windows, the use of light wells, or light shafts"* (American Hotel & Lodging Association, 2010). It includes the day lighting strategies as well as the need to reduce energy consumption.

5.3.3 Passive Heating

There are different definitions for passive heating (PH) and thermal comfort which will be explained and discussed as follows. Passive solar heating has been defined by Friedman et al (2009) as *"A system of features incorporated into a building's design to use and maximise the effects of the sun's natural heating capability"*. This refers in one way or another to the design elements and how they can be installed through the building construction in order to benefit from the natural heating. It is claimed that there is a difficulty in defining thermal comfort because there are two different factors that should be taken into account in order to make a space comfortable for users. They are environment and personal factors. Thermal comfort is defined in British Standard BS EN ISO 7730 (as cited by the Health & Safety Executive, 1991): *'that condition of mind which expresses satisfaction with the thermal environment'*. Satisfaction plays a clear role in thermal comfort which in one way or another means the EUs' satisfaction. This view combines user and environment as a dynamic system. That is to say, the environment cannot be considered and the user ignored or vice versa. Thermal comfort "*refers to comfortable indoor conditions (temperature, humidity, air movement)"* (Nayak, 2002). There is no clear indication of user consideration but the definition refers to comfortable conditions that are related to indoor comfort. Thermal comfort has been looked at as *"The temperature in the building to* *will have a big influence on the energy used*" (Nicol, 2008). The issue here is how to optimise the temperature to reduce energy consumption and not user behaviour. Passive solar is defined as *"A design system used to manage heat gains through daily sunlight with the aim to reduce the use of conventional heating methods"* (RAIC, 2008). There is a similarity between this explanation and the previous one, where both refer to compliance with the temperature to reduce energy usage. PH is also defined as "*A building's structure (or an element of it) is designed to allow natural thermal energy flow, such as radiation, conduction, and convection generated by the sun, to provide heat"* (American Hotel & Lodging Association, 2010). As can be seen from these definitions user needs are not placed as central requirements when specifying design functionality.

It is evident from these definitions that there is a large element of combination between PDS and end user comfort. Hence, it is unimaginable that sustainable design can be delivered without considering the end user needs as the main drivers for the design of efficient building assets. Thus, embedding these PDS with user needs into the design process will assist designers to optimise user aspiration. This in turn would result in prolonging the design service life of building assists.

5.4 User Centred Passive Building Design Process

The second component in the proposed conceptual model (see Figure 5:3) is the process by which passive design strategies are linked with EU needs. The process is summarised as follows (further discussions are provided in section 5:7)

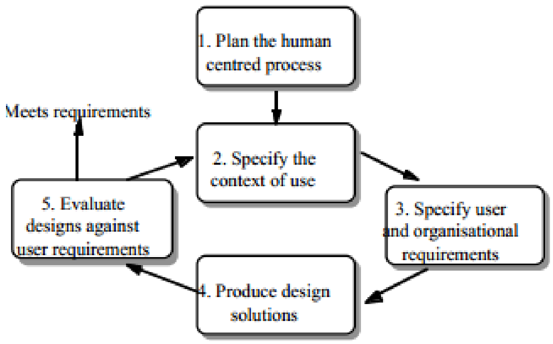


Figure 5:3: User Centred Design Process (ISO 13407, 1999, p.6)

- Specify the context of use: the purpose of this stage is to identify the user, usage environment and the point for using the product.
- Specify User and Organizational Requirements: identifying the factors that can enhance user role to use the product without any obstacles.
- Produce design solutions: the solutions that have been suggested to fulfill user needs such as interaction, interoperability and portability of the product.
- Evaluate Designs against Requirements: answers the question to what extend the end proc ct meet user needs

5.5 Passive design human attributes

The third component of the proposed model considers the interaction between EU requirements and PDS. As stated previously this was developed based on ISO 9126. There is a certain similarity between the design ATTs advocated by the standard and the building design performance measures. This standard includes six main ATTs and their S-ATTs as shown in Figure 4:1.

The ATTs in the figure are used as a base for developing the new conceptual model; the researcher refers to them as PDHAs. Other researchers define PDHAs as: factors that capture the needs, wants and limitations of end users in relation to functionality, performance, maintainability, reliability, usability and flexibility. This study modified the ATTs of efficiency and portability to be performance and flexibility respectively. This modification is necessary to reflect the characteristics of the building design process. As illustrated in Figure 4:1, the PDHA consists of 6 main ATTs. These ATTs are subdivided into several S-ATTs. The list of EU S-ATTs has been extracted from the literature review and case studies, as shown in the previous chapter. The following sub-sections provide the definition of each PDHA's main ATTs.

5.5.1 Passive Design Functionality (PDF)

This ATT is defined as: a set of design determinants that relate to the existence of a set of PD functions (i.e. Ventilation, Lighting and Heating) that fulfil user needs.This driver is characterised or measured by five S-ATTs which are (1) Site, Orientation and Vegetation (2) Building form (3) Space planning (4) Roof (5) Façade and envelope. Each of these S-ATTs is assessed by several EU satisfaction metrics, as will be briefly introduced. Also these EUFs will go through the UCD process as illustrated in Figure 5:4.

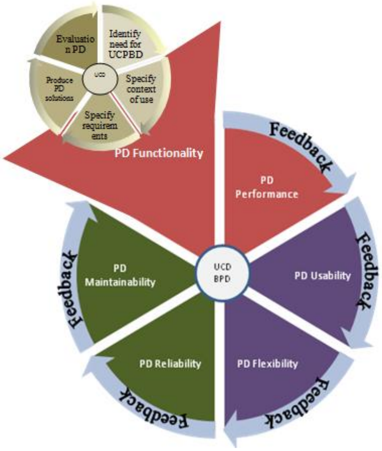


Figure 5:4: The correlation between UCPBD process and PDF

5.5.2 Passive Design Performance (PDP)

It is proposed to define this ATT as: a set of determinants that measure passive design functions' performance under stated user conditions. In the proposed model, this research determined seven A-ATTs for the performance driver. These are (1) Site performance, (2) Space performance (3) Thermal comfort (4) Ventilation (5) Lighting (6) Acoustic (7) Adequacy Consumption and Strategies. Each of these S-ATTs is composed of several EUFs. These EUFs are used to assess the design performance. Also, these EUFs will go through the UCD process as illustrated in Figure 5:5.

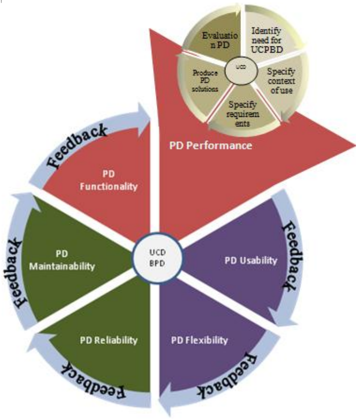


Figure 5:5: The correlation between UCPBD process and PDP

5.5.3 Passive Design Usability (PDU)

This ATT is defined in the research as: a set of attributes that relate to operability and compliance of passive design strategies to regulation standards and user operational efficiency. Its S-ATTs are (1) Operability (2) Human Behaviour. These S-ATTs are assessed by several factors that enhance the usability of building assets. The factors for each S-ATT vary. Also, factors will go through the UCD process as illustrated in Figure 5:6.

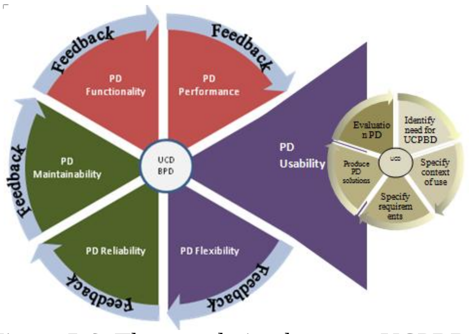


Figure 5:6: The correlation between UCPBD process and PDU

5.5.4 Passive Design Flexibility (PDFL)

The PDFL is defined in this research as: a set of attributes that relate to the ability of passive design strategies to be remodelled to satisfy new use conditions. Flexibility driver is composed of two S-ATTs which are (1) Future Adaptability (2) Flexible Space. These S-ATTs are measured based on EU satisfaction metrics. Also, the EUFs will go through the UCD process as illustrated in Figure 5:7.

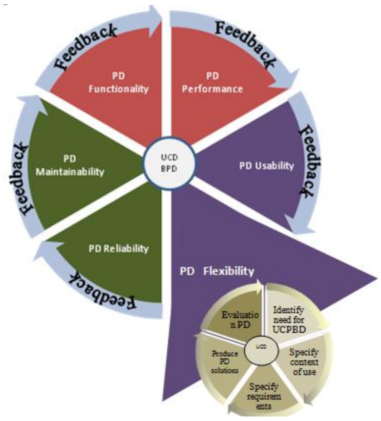


Figure 5:7: The correlation between UCPBD process and PDFL

5.5.5 Passive Design Reliability (PDR)

The researcher defines PDR as: a set of determinants that relate to the capability of passive design functions to maintain their level of performance under user stated conditions within the design service life period. This driver is made up of three S-ATTs which are (1) Durability (2) Material Reliability (3) Resilience. Each one of them is measured by several factors' reliability metrics. Also, factors will go through the UCD process as illustrated in Figure 5:8.

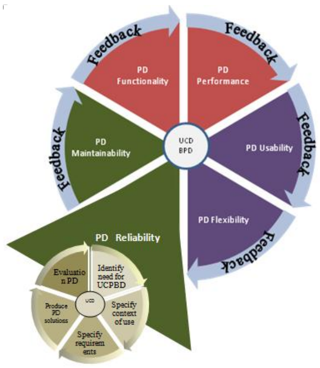


Figure 5:8: The correlation between UCPBD process and PDR

5.5.6 Passive Design Maintainability

The researcher defined PDM based on the definition from ISO 9126. PDM is defined as: a set of determinants that relate to the ease of inspecting, maintaining and modifying design to satisfy continuous evolving user needs. This driver has three S-ATTs (1) Standardisation (2) Material (3) Accessibility. Each one is measured by several factors which are extracted from the literature review in a way that enhances user needs. All factors will go through the UCD process as illustrated in Figure 5:9.

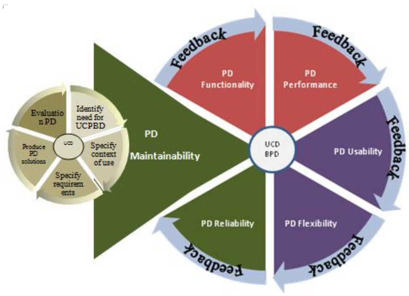


Figure 5:9: The correlation between UCPBD process and PDM

5.6 Feedback

The last component in the proposed model is the feedback loop. The evaluation results of each generated design solution are feedback through the stages of the UCD processes. The feedback loop is considered as a dynamic process by which enabling and effectuating EU conditions are brought together through simulation and sensitivity analysis to test the robustness of the generated design solutions. From this perspective, the designer should learn from previous EU experiences and feed these back into future design solutions. As shown in Figure 5:10, the feedback should be based on the life cycle of the building. In the design stage the feedback should include both the brief and EUs' aspirations. Then scenarios based on the features of the existing building should be created. Finally, the performance of the existing building should be assessed too. This will comprise the feedback to use during the design phase to maximise EU satisfaction and environmental comfort (Andreau and Oreszczyn, 2004 as cited in Dursun and Ozsoy, 2007).

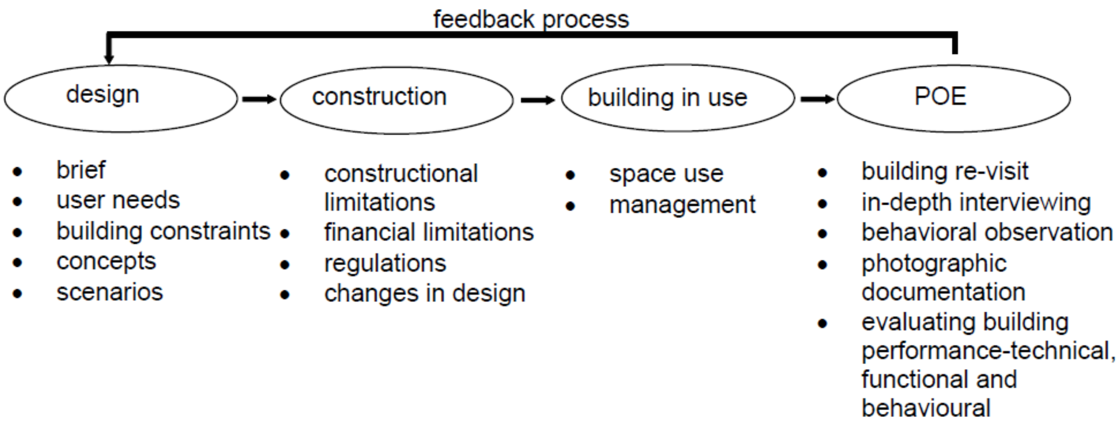


Figure 5:10 : Feedback process (Dursun and Ozsoy, 2007, p.88)

5.7 Implementing the model

The proposed model is implemented through the iterative processes shown in Figure 5:11. The implementation process links current design processes with passive design and end user needs. The stages of the process are considered to be vital in linking passive design strategies and end user needs' aspirations. The process stages are the foundation on which user centred passive building design is implemented. This process is conceived to reflect the special characteristics of building design processes. The aim of the procedure is to help the designer to consider iteratively the components of the model to ensure that needs of the end users are fulfilled. This process is divided into three main stages as shown in Figure 5:11.

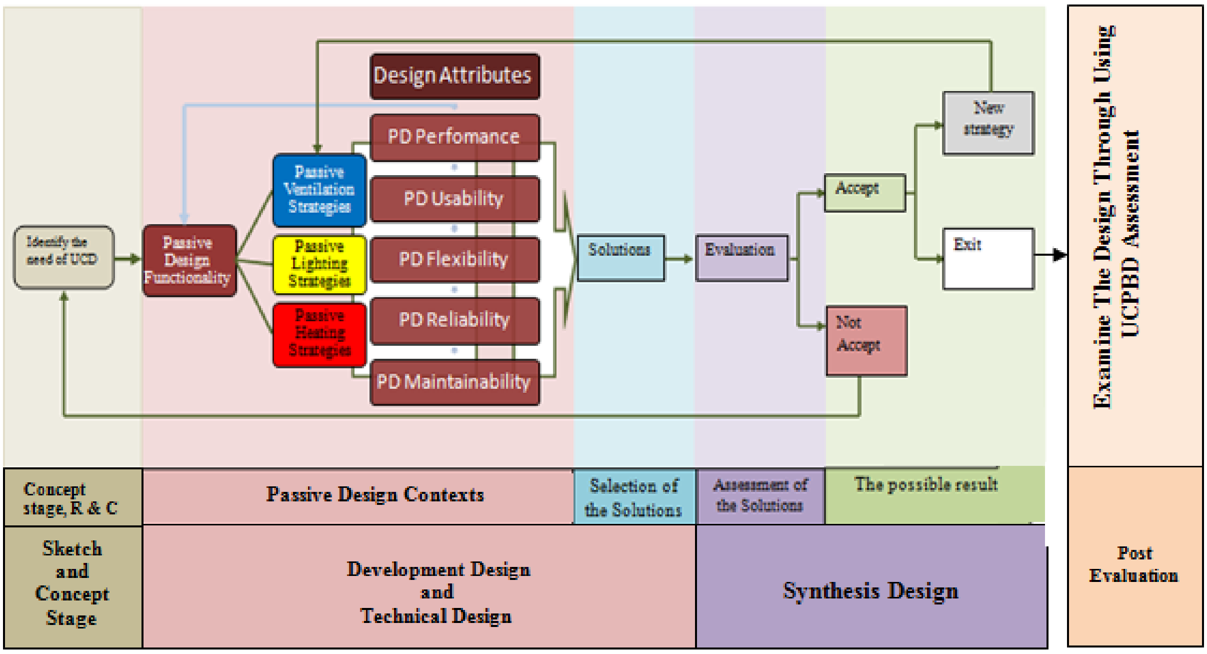


Figure 5:11: User Centred Passive Building Design Process. (Concept stage, R: Requirements and C: Context)

5.7.1 Concept and Sketch stage:

The implantation process starts at the concept and sketch stages. The main aim here is to identify the need for using user centred design approach. The designer will work to extract the client aspirations and the expected building functional characteristics, life span and in use requirements. *Andresen et al (2008) pointed out "architects and engineering provide mutual inspiration in a way that fulfilling the design functions. Gething* (2011) suggested that ecological design strategies requirements ought to be elicited at the concept design stage. *It is expected that the end users' needs are established along with the pattern and performance requirements for passive lighting, ventilation and thermal. The designer is expected to consider space layout, plan depths, form, orientation, and other relevant design strategies in relation passive design functional requirements and users aspirations. The designer must keep the* end users' requirements in check in every proposed concept sketches and design solutions. By doing so it *augments the chance of delivering an asset that fulfils end users aspirations*. The different between the concept stage of the proposed model and other traditional design methods is in the systematic consideration and classification of end user factors to create design solutions that are users' complaint, durable and resilient to rapid changes.

5.7.2 Design and Development Stage

The design development stage is composed of two steps. These are passive design context and solutions generation. In the first stage the main issue that need to be considered here is the translation of the captured information in matrices, concept sketches and other forms to create design technical solutions. Also, it is expected that design specifications and technical details are conceived in relation to end user needs and other contextual data. It is expected here that a designer will specify a design function then try to check if the specified function concurs with the user expectations. This can achieved through using advanced modelling and simulation to prove the proposed design. In doing so the designer must reconcile between all the conflicts that may exists between function performance and end user attributes. For example, to design a window, a designer should first indentify the functional requirements of the space in relation to passive passive lighting, ventilation and heating. Based on the functional requirements and user attributes the designer will identify a suitable strategy that realizes all the preconditions. The process here differs from other design processes through the fact that the five user design attributes are considered in every proposed design solution. Thus the driving theme for deriving design solutions is functionality that responds to end-user design attributes. The derived design solutions, from the previous stage, are subjected to testing against the passive design strategies to ensure that the design performs as perceived as well as satisfies end user aspirations. The selection process is informed by architects' experience and perception of the real world or usage scenarios. The design solutions should mainly be selected on functionality and the level of end user factors inclusion in the solutions. It is here where the end user assessments tool can play a major role in indentify solutions that are EUs compliant.

5.7.3 Design Synthesis Stage

This consists of assessment and adoption of the proposed design solutions. Andresen et al (2008*) explained "this stage shows the extent to which the design meets owner requirements".* The designer should be experienced enough to evaluate his/her work to insure integration and compliance with end users factors. It is the last possible chance to redesign and rethink the proposed solutions before producing the working drawings. It is more cost effective to change design at this point than a later stage. The adopted design solution should be subjected to what if analysis scenarios to identify and iron out any performance and end user compliance issues. This assessment should not be limited to present requirements but also future usage scenarios. At the end of the assessment there are three possible outcomes. The first outcome is that the proposed design solution meets EU needs and partially fulfils some of the PD function requirements. Thus the solution needs to be modified to eliminate the inadequacy in the function. In this scenario, the designer has to go back to the second stage and re-start the design process all over again as explained above. The second possible result is that EU needs and functional requirements are met. Thus, design adopted, and the process completed for the design task in hand. The third outcome, the designer discovers various omissions in relation to end user factors integration and passive design functionality. In this situation the designer has to re-start from the concept stage go through the process as described previously.

5.7.4 The Post Evaluation

After all design tasks are completed it is possible to evaluate the whole building for compliance with end-user requirements. This process is similar to certification of the design compliance (similar to BREAM). The main five the end user factor s can be developed as tool to serve this purpose.

5.8 Retaliation between the Components of the Model

The main implication of the proposed model is the systematisation of extracting and incorporating EU factors into passive design solutions. Each part of the model could play clear role in enhancing designer responsibility to fulfil user needs in parallel with the consideration of environmental issues. This conceptual model offers new insights into innovative design practices. The researcher expects that designers would be interested to know the influence of the end user needs on the proposed design passive building strategies. By doing so it will lead to meet the end user requirement and reduce their complains in post occupancy stage. This model will also lead to maximise user satisfaction. The inclusion of a diversity of attributes and viewing user needs from different perspective can help the designer to mitigate any future dysfunctional that might emerge in the operation of building assets. For this reason the proposed model is an innovation that could assist designers to meet user needs and ecological concerns. In terms of fulfilling environmental issues, the three dimensions of the passive design strategies are considered as the hub of this model. Considering the passive design strategies that relying on natural environment will enhance the creation of sustainable design solutions. These dimensions are integrated with the passive design functionality as appeared on figure 5-11. This is necessary so for avoiding conflicts and understating couplings between strategies that have a dual function. All design factors that influence these three dimensions are grouped into sub-attributes of passive design functionality as shown in the framework in figure 4:1 in chapter 4. The idea here is that when a designer wants to assess the functionality of particular passive design strategies, he/she must assess the impact of all EU factor on the strategy. To do so the designer must go through the five stages the five stages of the process as shown in the figure 5-11. The total user attributes that are extracted from literature review is 132. These factors are assessed for their importance through a filed study or questionnaire. The results from the quantitative analysis are used to reduce and cluster the users' factors into

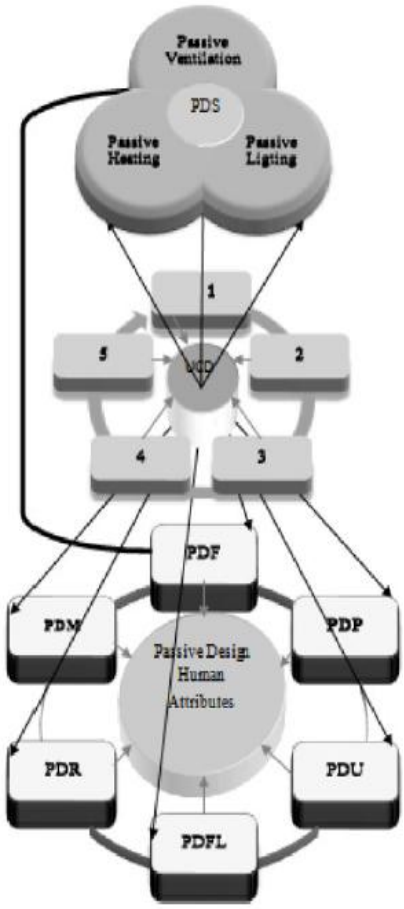


Figure 5:12: The correlation between the model components

manageable sets without losing a large amount of information. Details of these are presented in chapter in figure 6-3 in chapter 6. Then the result of this process is used to create a tool to assess design compliance with the incorporation of EU factors. Chapter 11 presents the rationale and results of the assessment tool. By using the proposed tool the designer maximize the inclusion of user needs into the design solutions. If the model is adopted it could revolutionize the way designers perceive end user needs.

5.9 Discussion

The ISO standards that are used in software design have proven to be valuable in integrating EU needs into all software products that exist in the market nowadays. Similarly if such a system, as proposed in this work, is adopted in the design of PB it will revolutionise the building design sustainability agenda. PD is one of the approaches that are used to mitigate environmental impacts. It is through the optimum linkage between functionality, performance and EUs' needs in building assets design that environmental impacts can be reduced. The UCD process proposed in this work can maximise the level of EU satisfaction and comfort leading to an increase in building service life. Dealing with the perceptions and psychological needs of the building EUs and how they interact with the facility in a systematic way as proposed in this study will certainly enhance the chance of delivering highly performing buildings. This chapter has demonstrated how the socio-techno-economic drivers ought to be considered in PD of buildings in order to meet EUs' requirement. For this reason, it is extracted tens of EUFs.

5.10 Summary of this Chapter

The UCPBD process and PDHAs make up the core of the proposed conceptual model. This work has considered EU aspirations from physical, economic and psychological aspects. The proposed model will provide added knowledge to the existing methods for helping the designers to meet the EUs' needs in the design of passive buildings. Hopefully this will contribute to the satisfaction of the EUs and lead to the design of highly performing building assets. For this reason, meeting EU needs in each ATT requires investigation of their demands. Thus, their needs will be the criteria of a research questionnaire that will help to assess and test the model. Discussion of this questionnaire will form part of the rest of the chapters of this research. This study may go a long way to build up capability and knowledge in this vital area of practice and research. Further work will consolidate the validation of the selected EUFs and develop a tool to assess the building design for the inclusion of design that considers the EU.

Chapter Six: Research Methodology

6.1 Introduction:

Research methods can be classified as quantitative, qualitative or both. There is a difference between quantitative and qualitative methods. The quantitative method is usually dealing with numbers; in contrast, the qualitative method is dealing with information or providing data. Russell (2000) indicated that the quantitative research method is usually used to test a model or hypothesis that is established based on a theory or theories. In terms of the qualitative method, it usually covers investigation and study of the information in natural settings (Leedy & Ormrod, 2005).

This research study is to describe the EUFs that influence the design of PBD during the life cycle of the design from the concept until operation. For this reason, it has used both qualitative and quantitative approaches. Yao (2004) stated that the hybrids between research methods can lead to enhancement of the research strengths and elimination of any weak research points.

This research has been started by using qualitative data gained through a critical literature review. The critical literature review has covered investigation of the suitable methods that bridge the gaps between EUFs and PDS. Then, the researcher has studied and determined the PDHA through detailed reading of various chapters. Based on the critical literature review, the quantitative method has been developed. This was through developing a questionnaire based on the PDHA and EUFs that were extracted from the literature review. The survey will gather the architects' perceptions about the EUFs that have been identified in the conceptual mode. This will lead to assessment of the most effective factors and the designer perceptions on integration of EUFs within the PD process.

6.2 The research methodology theory

As has been introduced above, there is a difference between the quantitative and qualitative methods. For this reason, this section will review the advantages and disadvantages of each method before explaining the research methods that have been followed in this research.

6.2.1 Qualitative: Critical literature review

The need for a literature review is to find out what is already known about the area of research, in order to avoid 'reinventing the wheel'. It is also used to build an argument about the significance of the research area. This leads to create a clear vision to achieve the aim of the research. In addition, the concepts and theories which are relevant to the area of research can be identified. Moreover, there is a need to identify if there are any significant controversies or inconsistencies in the findings in the area, as well as any unanswered research questions (Bryman, 2008). The literature review can help the designer to identify the gap in the research and to identify the weakness and the strengths of the research. Also, the literature is the background of the research, which is based on it. Therefore, we start to look at the methodology as well as investigation the EUFs through each one by one.

6.2.2 Qualitative: Questionnaire Design

This chapter is to review the qualitative research methods and the process that has been followed to design and develop the final version of the questionnaire. However, this method has advantages and disadvantages for this research, as cited by various authors as follows:

The advantages of using a questionnaire:

Powell (1997, as cited by Grover et al, 2010) classified the advantages of using a questionnaire and email survey, and applied it to six categories.

- It will stop interviewers distracting the respondents.
- The importance of considering the questionnaire format, hence, that will help to eliminate differences during the questioning process.
- The questionnaire could enable the respondents to have thoughtful answers, as well as give them the opportunity to complete it at a suitable time.
- The questionnaire format can be designed to be easy for both data collection and analysis.
- This method can allow the researcher to collect a large amount of data in a short time.
- Questionnaires sent out through email will be cheap to manage.

The disadvantages of using a questionnaire:

There is nothing a fully completed, which means as there are advantages there are disadvantages too. Powell (1997, as cited in Grover et al, 2010) identified some other negative features which could occur when applying an email survey.

- The contact between the respondent and the subject and the researcher.
- When the respondent needs a clarification, s/he will not be able to ask. However, any queries could be asked via an email, if the questionnaire only contains simple to answer questions, so this will eliminate this concern.
- Highly opinionated people are more likely to respond to a questionnaire.
- The sender should expect a low rate of respondents; this can be attributed to various possibilities such as the experience of respondents, and difficulties regarding the questionnaire structure or formulation of sentences.
- Some questionnaires contains seem to be resistant, which can demotivate the respondent from answering correctly.

The questionnaire of this research was designed to determine EUFs and their effect on designing PBD. The survey data was extracted from reviewing the literature before developing a UCPBD model. This will help the designers (architects) to ensure whether their building is meeting EU requirements or not. This chapter will describe the methodologies which have been used to develop the questionnaire and the process from the concept until the final version. The finding will be analysed by using SPSS and Excel to assess the perception of respondents. The architects' responses will be used in developing the UCPBD model and measuring its effectiveness for EU needs.

6.3 Rationale for designing the survey

There are various research strategies that can be used depending on the situation, as illustrated in Table 6-1, which classifies the research strategy into three types (A) the type of research questions (b) the control of the researcher (C) focus on contemporary events (Yin, 2003). As illustrated in Table 6-1, this research could be limited to three questions: what, how and who. For this reason, the possible strategies will be archival analysis and survey, because this study is not intended to answer the 'why' question. Also, this investigation will not be required to control for behavioural events. This means that there is no need for experiments or case study in this research. As the researcher does not want to answer why, the history can also be excluded. Based on that, the researcher has concentrated on two parts in designing the survey: the first part is validation of the survey through delivering the questionnaire to the experts in the particular research area. This task was to ensure that the survey contents covered the main aim of the research topic and to confirm that all the selected factors will help to answer the research questions and problem. The second part is collection of the quantitative data through using an online survey. The following sections will explain the process and tasks that have been followed to develop the questionnaire.

Strategy	Form of Research Question	Requires control over behavioural events?	Focuses on Contemporary events?
Experiments	How, Why	Yes	Yes
Survey	Who, What, Where, How many, How much	No	Yes
Archival Analysis	Who, What, Where, How many, How much	No	Yes/No
History	How, Why	No	No
Case Study	How, Why	No	Yes

Table 6-1: Relevant situations for different research strategies (Yin, 2003, p.5)

6.4 Research methods process

The research method of this research includes six main tasks, as shown in Figure 6:1. The first task is to determine the main aim, objectives, problem statement and hypothesis. The second task is to review the architectural theories, in order to identify the PDS, suitable theories to integrate EU needs, and the PDHAs. The latter was developed to extract the EUFs based on a literature review of PDHAs which are classified into six main As. The third task is to develop and validate the questionnaire with an academic who is an expert in the relevant area, before delivering the end questionnaire. The fourth task is data collection and analysis starting from descriptive results to data reduction and clustering factors. The fifth task is developing an assessment tool. The discussion and conclusion chapters form the final task. Each of these tasks will be explained one by one in the following sections which is adapted based on (Mohd Rahim, 2011).

6.4.1 Task 1: Initial research

The first part of the research methods comprises identifying the research aim and the research problem and making sure there are no other approaches or theories that already exist which have tackled the problem under investigation. This part is also used as a platform for extracting the necessary knowledge for forming EU design constructs. This will be discussed in the following section.

6.4.2 Task 2: Literature review

This task is based on reviewing the critical literature review. The literature review has been divided to four main stages as follow:

6.4.2.1 Sub-task: Review design and architectural theories:

In this section of the research (see Chapter 2), architectural design theories since 1956 until the present have been reviewed. This review has covered various stages of architectural theories' development. Reviewing the theories was to ensure there are no theories or approach that match the proposed theory and model.

6.4.2.2 Sub-task: Review the PD

PDS have been divided into three dimensions which are PLVT. Then their design elements have been determined. The PDS are revised and classified before being involved in PDF, in order to avoid repeating the PDS in this ATT; also, some strategies have dual functions, for example, a window could be PL and PV. They have been listed depending on their relation to design function as shown in Chapter 4. In this section also, some of the definitions of PDS have been reviewed, to see whether they are meeting EU needs or not and to see the contents of each definition.

6.4.2.3 Sub-task: suitable method

This deals with the process used to develop the conceptual model used in this research. The process consists of several iterative steps, as shown in Figure 6:1. The process starts by classifying PDS into three dimensions. Then, the PDS are reviewed to ensure that their functionality is designed based on EU needs.The third stage of the process is to search for a design paradigm that satisfies the conditions set in the previous step. A UCD theory, which is used in the IT industry, was investigated for its suitability for PBD processes (see Chapter 3). The researcher found that there was great similarity between IT systems and building design processes. Based on this finding, some aspects of the theory were modified to harmonise with PDHAs and contents. Figure 6:2 shows the process stages.

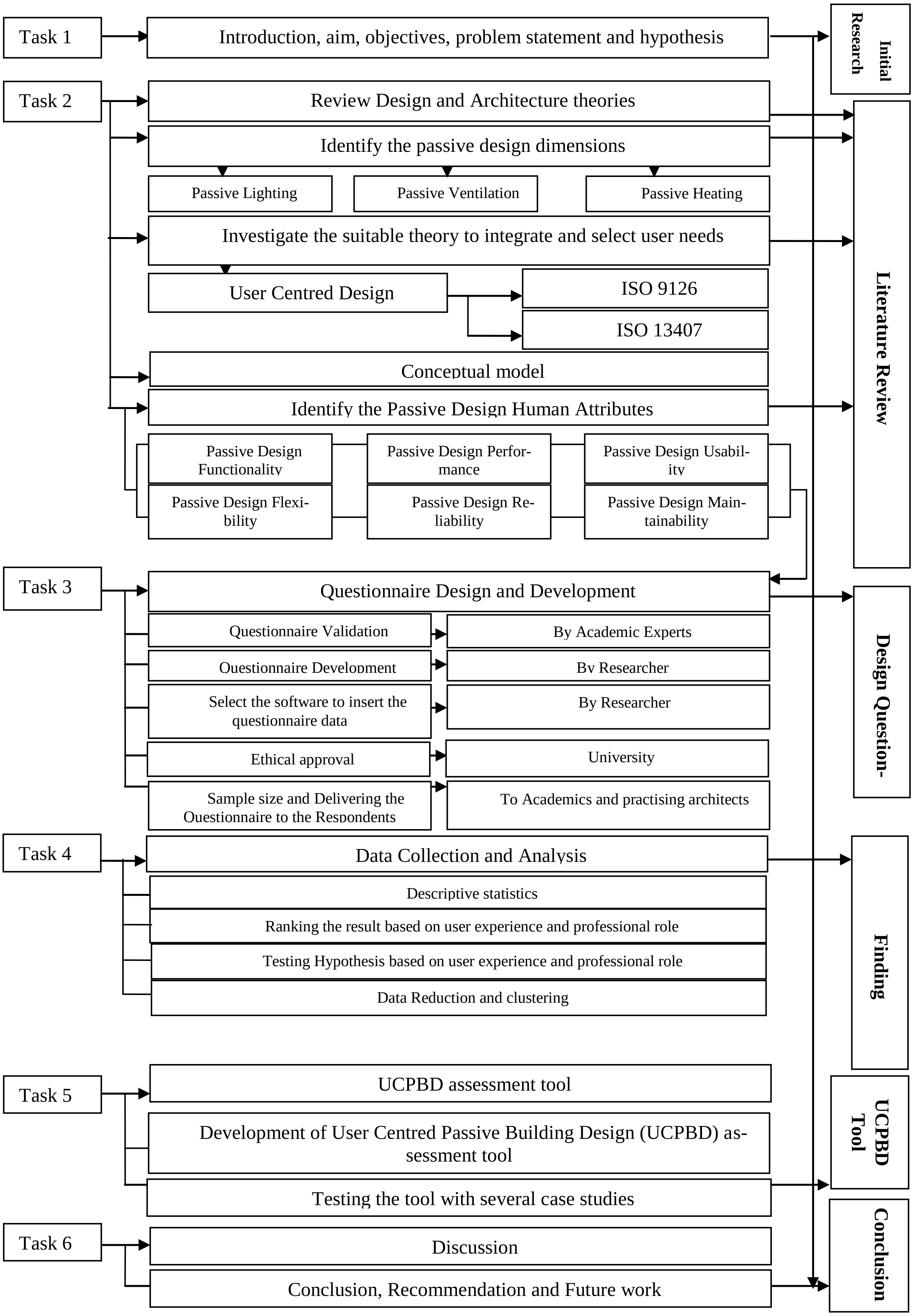


Figure 6:1: Research Process (This style adopted from Mohd Rahim, 2011)

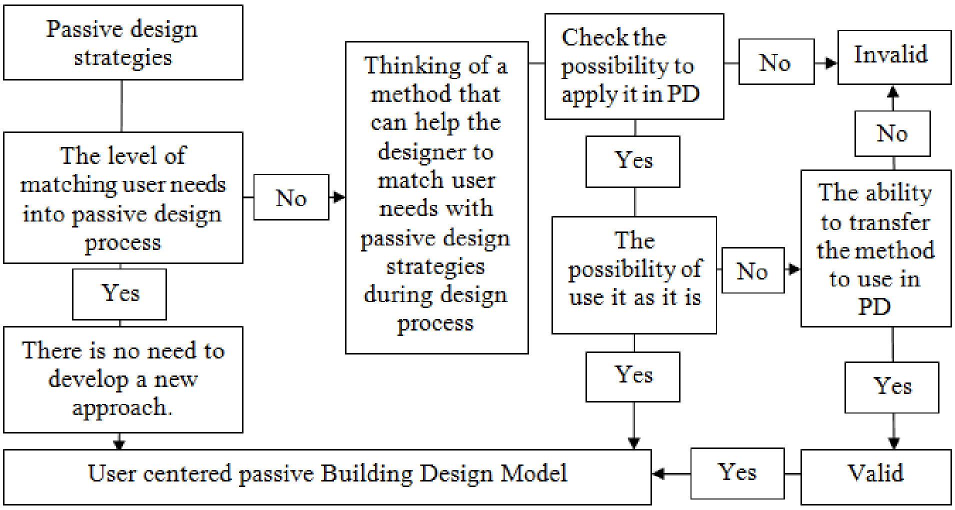


Figure 6:2: The process of the research methods to develop a UCPBD conceptual model

This sub-task is to determine the theory that can be used to integrate EU needs into PD. For this reason, UCD is selected as the suitable theory, even though it is used in the IT industry. This theory is about integrating EU needs into software. One of the motivations for investigating this theory is that it has been applied in various sectors such as education and health. Also, during reviewing this theory, the researcher paid attention to classifying the EU who the design was made for. There are two main standards which are established based on this theory. ISO 13407 is the first one, which is about the design process approach that the designer can follow to ensure meeting EU needs. The other standard is ISO 9126, which is comprised of the software ATTs. It has been reviewed with regard to the possibility to use it in PD.

6.4.2.4 Sub-task: Conceptual model

In this stage, the conceptual model, which comprises PD dimensions, the UCD process (ISO13407) and PDHAs, has been identified. The methodology that is followed to develop the conceptual model is that based on critical analysis of the literature and prototype modelling. The analysis followed by this research is based on system development methods. The researcher has carried out an intensive literature review into UCD methods and factors in the building, engineering and IT industries. The investigation spans from 1956 to date. The literature showed that there are no coherent models in the building industry that capture the total E-U factors as portrayed in ISO standards. However, in the IT industry, the theory of UCD is well advanced and developed. Thus, the extracted knowledge from literature was classified according to ISO 13407 and ISO 9126 standards. Also, these standards are developed based on system development methods. Hence, the researcher used ISO 9126 to generate EUFs and ISO 13407 for developing a systematic process for integrating UFs into PD; and 132 EU factors were extracted. The selected UFs are currently being assessed for their effectiveness in satisfying EU needs (see Chapter 5).

6.4.2.5 Sub-task: Passive design human attributes

Classified PDHAs have been used to identify six main As, which are adopted based on ISO 9126. The first A is the PDF including PDS and it is classified into five main groups (site, orientation and vegetation, building form, space planning, roof and façade). Then, the EUFs have been extracted from reviewing the other five As which are PDP, PDU, PDFL, PDR and PDM. These As are classified based on ISO 9126 with modification to two As: efficiency and portability. Efficiency is replaced by performance, so that the performance is more comprehensive; and portability is replaced by flexibility, which is more familiar in the building industry. Each one of them including several S-As which of course involved several EUFs. The main aim of this research is to classify the EUFs and harmonise them with PDS. For this reason six main As have been produced as main groups for EUFs. The As are as follows: PDF, PDP, PDU, PDFL, PDR and PDM (see Chapter 4). The EUFs which have been selected were extracted based on the literature review. Also, they have been adopted based on ISO 9126. 132 factors have been listed. Then, the list of EUFs has been related to the PDAs. The survey has been divided based on the six As.

The first ATT was PDF. The EUFs of this part have been listed under five main drivers (1) Site, orientation and vegetation (2) Building form (3) Façade and Envelope (4) Space planning and (5) Roof. The second A is about the PDP. Also, this A covered several EUFs which have been listed under seven main drivers: (1) Site performance, (2) Space performance (3) Thermal comfort (4) Ventilation (5) Lighting (6) Acoustic (7) Adequacy Consumption and Strategies. The third part was the usability, which included two main drivers: (1) Operability (2) Human Behaviour. The fourth part was PDF, which also included two main S-ATTs: (1) Future Adaptability (2) Flexible Space, to cover the list of EUFs. The fifth part was PDR which covered three drivers (1) Durability (2) Material reliability (3) Resilient. The final part was PDM, which included (1) Standardisation (2) Material (3) Accessibility. The list of As accounted for 132 factors, as shown in the following model and listed in Figure 6:3.

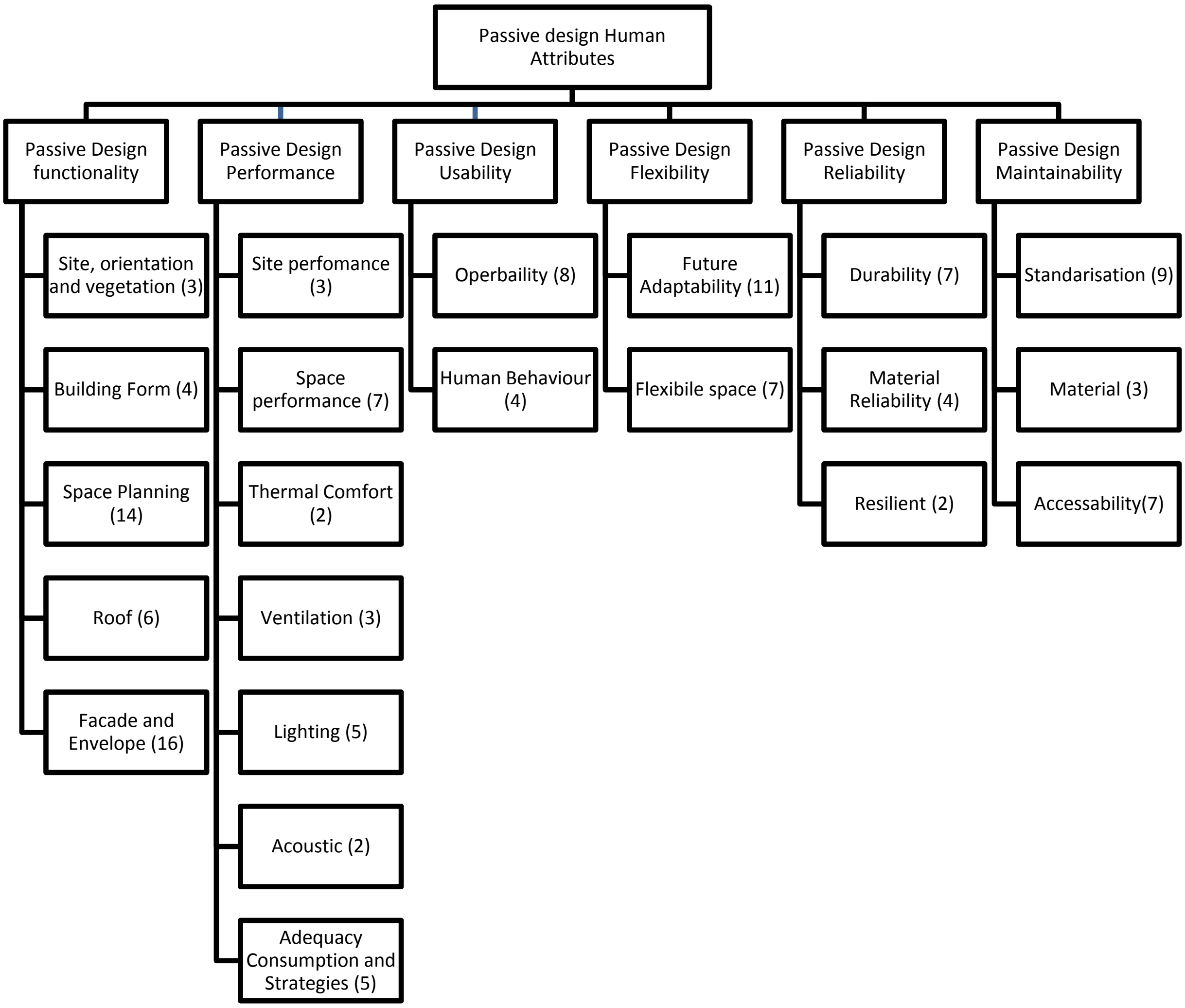


Figure 6:3: The total number of EUFs

6.4.3 Task 3: Questionnaire Design and Development

The researcher has selected this method based on the advantages of the questionnaire which have been listed earlier in this research. The questionnaire is selected as an appropriate method in order to examine the long list of selected EUFs. These factors have been selected based on literature about the PDS and UCD. The listed factors were also provided based on the researcher's knowledge as well as discussion and development with the supervisor. The literature review stage was the foundation of building and creating the survey contents. It has meant that the questionnaire has been divided in to seven parts. The first part has provided an overview about the research and idea. Then the six As and their EUFs were listed together to be ranked by the architects and practising architects. Then the architects' views regarding considering EU needs were requested.

The survey is designed to ask the architects about the main research question which is about the EUFs and their effect on PBD. The detailed question is to determine to what extent the architects are integrating EUFs at various ATTs.

The first part of the questionnaire, which included six ATTs, has measured their effectiveness on the PDHAs. The respondent is required to give a score to each EUF based on the level of its effectiveness. In Table 6-2, the scale that has been used in the questionnaire is illustrated. It included five scales. ‘Very ineffective’ and ‘ineffective’ were allocated for the factors that are not effective on user UCPBD, whereas ‘neutral’ is for EUFs that have unbiased effectiveness. Finally the ‘effective’ and ‘very effective’ EUFs are described as the highest degree of effectiveness of the EUFs in UCPBD. The sample questionnaire is illustrated in Figure 6:4.

Very ineffective	Ineffective	Neutral	Effective	Very effective

Table 6-2: Scale based on EUFs’ effectiveness

1- How effective are the following site, orientation and vegetation design factors in improving user experience in passive building design?
Please check one box

	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
Use vegetation for optimum lighting, ventilation and thermal comfort					
Orient the building for optimum lighting, ventilation and thermal comfort					
Use nearby landforms and structures for wind protection and summer shading					

Figure 6:4: Sample of the first part of the design questionnaire

The hypotheses used in this task are based on effective levels:

A_x: There is no statistically significant difference between the architects’ perceptions regarding the level of effectiveness of EUFs on PBD.

Ay: There is a statistically significant difference between the architects’ perceptions regarding the level of effectiveness of EUFs on PBD.

The second rate is to test whether the architects are keeping users in their mind when they consider the PDHAs or not. The rate involved three categories, as shown in the following table (6-3):

Never	Sometimes	Always

Table 6-3: scale based on the level of keeping the EUFs in the architect’s mind when designing PBD.

The third part was to ask the architects to rank the level of keeping EU needs in their mind during designing each A. The researcher is investigating the perception of architects about keeping EUs in their mind during the design process. This question will be asked in terms of the six As. Figure 6:5 shows a sample of this part.

Current Practices:

Passive Design Functionality: [A set of design determinants that relate to the existence of a set of passive design functions (i.e. ventilation, lighting and heating) that fulfil user needs].

How often do you keep end user needs in your mind in relation to passive lighting, ventilation and heating when you specify passive design functionality?

Never	Sometimes	Always

Figure 6:5: The second part of the design questionnaire of the level of keeping the EU in the architect's mind when designing PBD

The hypotheses used in this task are based on participation consideration levels:

B_x: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PBD.

By: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PBD.

The architects were asked to tick the EUFs based on their effectiveness on UCPBD. This method is easy for both the respondents and researcher. In terms of the researcher, the data can be analysed and interpreted easily. For the respondents, the survey is easy to understand and respond to.

The last part of the questionnaire is general information about the respondents. The respondent's name, contact details, professional role and experience are the contents of the last part, as shown in the figure (6-6).

Personal information:

1- Respondent's name (optional)	
2- Contacts details if you wish to enter into prize draw for an iPad2 16GB (optional)	Email : Contact number:
3- Company name (optional)	
What is your professional role? ☐ Architect practicing ☐ Academic and Architect practicing ☐ Academic	
How many years of experience do you have? ☐ 0-5 Years ☐ 5-10 Years ☐ More than 10 years	
If you wish to receive a summary of our results upon completion of our study then please supply your name and contact email? - Yes [Contact details] - No	

Figure 6:6: The last part of the design questionnaire collects personal information

6.4.3.1 Sub-Task: Questionnaire Validation

The first draft of the questionnaire was shown to the researcher's supervisor and colleagues to gain their feedback about its wording, contents and layout. Their suggestions were considered and re-viewed many times in order to make the questionnaire understandable for the target respondents. Then it was pre-tested with the academic and researches who are experts in the area of environmental de-sign. The experts were identified based on their publications and research interests. The comments responses were received from (Sue roaf, 2011) (Isra, 2011) (Daniel Ryan, 2012). Their comments and suggestions were considered and integrated into developing the questionnaire. This method helps the researcher to confirm whether the factors, descriptions and questions are comprehensive and suitable for the research area.

The previous stage showed that there was a need for some modification of the survey. This was the reason for delivering the first draft to the experts in this area: in order to produce a questionnaire that is clear and understandable for the architects who will complete it. They will be asked to click the level of effectiveness of each factor separately. This will show their perception and the level of their knowledge. The process of designing the questionnaire is shown in Figure 6:7 below.

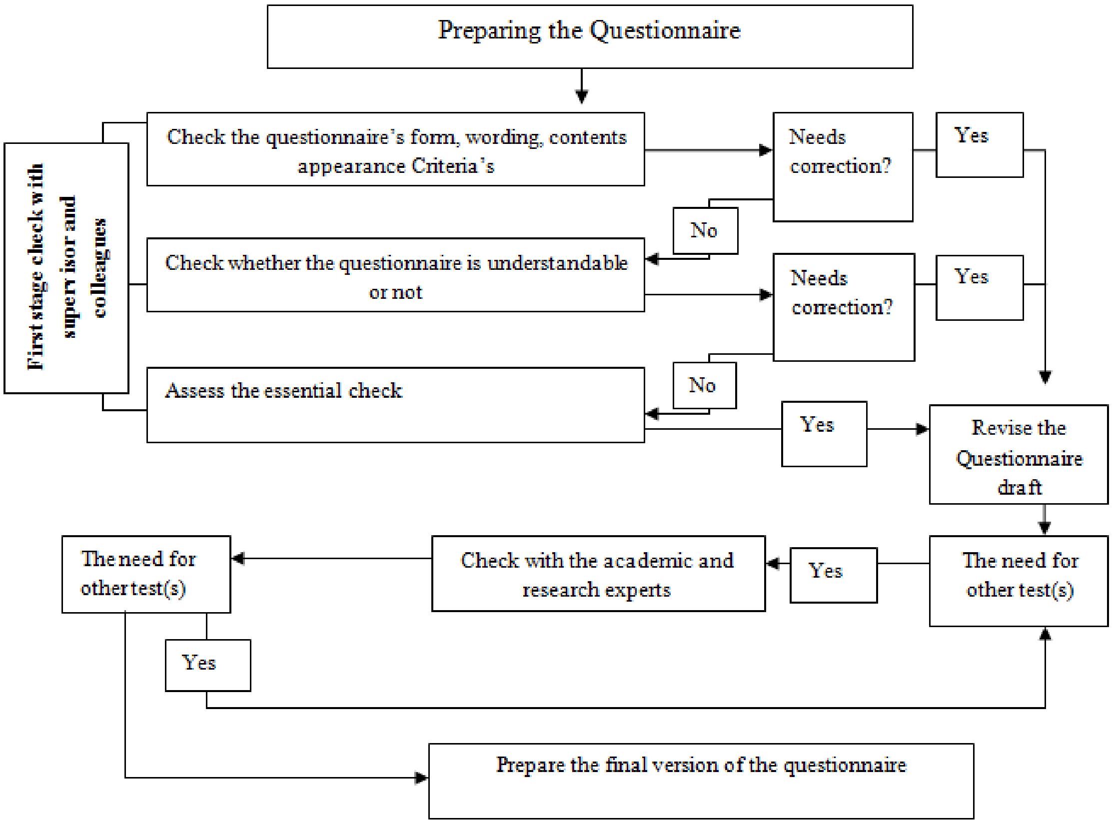


Figure 6:7: Questionnaire design process (This style adopted from Mohd Rahim, 2011)

6.4.3.2 Sub-task: Questionnaire development

The feedback of the academic experts will be included when developing the questionnaire, in case; their comments match the main aim of the research. In addition to that, the comments which have not previously been considered need to be justified.

6.4.3.3 Sub-task: Select the software

The software had been selected in a way that makes it easy to use for inserting the information. Also, it is easy for respondents to move on through it. Various types of survey software were considered, such as 2ask, Survey Monkey and Survey Galaxy and online survey. This research uses Create Survey, as it is available on the university website and it is easy to insert the data.

6.4.3.4 Sub-task: Ethical Approval

An ethical approval application form was sent to the University of Liverpool on 19 March 2012 to gain permission to involve human participants. A request for clarification of some aspects was received on 28 March 2012. The clarifications were made and the form was resubmitted on 28 March 2012. The researcher received approval to proceed with the data collection on 30 March 2012. A copy of the approval is provided in Appendix C and Appendix B is a copy of the questionnaire.

6.4.3.5 Sub-task: Sample size and Delivering the Questionnaire to the Respondents

In this research the questionnaire was distributed to architects in both fields, academic and practising, who are interested in environmental design and sustainability. These groups have been identified so that their research area is related to passive design, on the one hand. On the other hand, the questionnaire criteria cover the issue of PD, which means the designers should have at least some information or background in PD issues.

Architects with an interest in passive design were randomly selected. This group was considered to take part in the survey. Also, academics from universities worldwide were selected, based on their expertise in environmental design and PD. Their information and contact details were selected from the RIBA website and universities' websites. 138 questions were sent to 365 architects from both sectors, who were selected randomly. The score of the questionnaire was based on 5 points for the first part of the questionnaire, as follows: (1) Very Ineffective, (2) Ineffective, (3) Neutral, (4) Effective and (5) Very Effective. 1 and 2 scores indicated the least effective end user factors in PBD. 3 is a neutral effective factor that could be considered to develop the proposal model. 4 and 5 are the effective end user factors that play an essential role in developing this study's conceptual model. In the following table, the result of the questionnaire is given that all EUFs have a scale of more than 3, which is the neutral point, as shown in the mean value section. This means all EUFs that have been selected are accepted by the architects. 110 respondents completed the survey. This number of respondents was a good achievement, especially given that many respondents indicated that the questionnaire was too long. The percentage of respondents was 30.13%. This percentage is acceptable as per Akintoye (2000), who referred to the norm rate for survey responses as being between 20% and 30%. This percentage is considered as an acceptable percentage in cases where the author has no formal relationship with the respondents (Zoomerang, 2010). This means the rate can be increased in cases where the method of delivering the questionnaire is different, such through interviewing the respondents, or in cases where the researcher knows the respondents. 20%-30% is the average response rate and can be considered a realistic percentage (Sherrie, 2010). The typical response rate when using a web survey design should be between 20-30% (Couper, 2000). Addendum (2012) confirmed the same percentage can be classified as a contemporary acceptable standard. Prahalad and Hamel (1990) said that over 20% is an acceptable response rate for email surveys. In terms of email survey, some authors consider 24% is the normal response rate percentage (Sheehan and McMillan, 1999).

The questionnaire was delivered to the respondents who have been identified as three types, as follows: the architects who practice, those who are both academics and practising architects, and the academics. One of the strategies was to find out the architects and academic contacts, through using the architect office information at RIBA website as well as through universities websites. Several architects around the world are also experts on architectural design. To motivate them to fill in the questionnaire, they were offered entry into a draw to win an iPad. The draw process and winner is illustrated in Appendix M.

6.4.4 Task 4: Data Collection and analysis

This stage has five sub-tasks to analyse the data in detail, as follows: descriptive analysis, comparative analysis, testing hypotheses, data reduction and clustering groups; these are explained in detail below.

6.4.4.1 Sub-task: Descriptive findings

Two methods were used to analyse the findings of the questionnaire. The first method was to use mean value and standard deviation to find out the highest and the lowest effective factors. The mean value also helped to rank the factors and to know the highest and the lowest effective factors, as shown in Chapter 7. Using the SPSS program enabled the researcher to find the mean value and standard deviation.

6.4.4.2 Sub-task: Ranking findings

The SPSS program was used to compare the findings and rank the results based on the respondent's experience and professional role. Chapter 8 will give selected case studies from the SPSS to compare the results of respondents' experiences (M1:0-5 years' experience, M2:5-10 years' experience, and M3: More than 10 years' experience) and is based on the architects' professional role (L1= Architect practising, L2: Academic and Architect practising, and L3: Academic Architect). Also, the researcher used two methods as follows. Coefficient of Variation is a measurement that can help in comparing variables of various respondents. Severity index (S. I.) shows the rank of significance for each EUF.

6.4.4.3 Sub-task: Testing hypotheses

The third stage of data analysis is testing the hypotheses through using ANOVA one way analysis method. This also helps to identify the significant differences between the respondents. The results will be through checking the P value. In cases where the $P < 0.05$, the hypothesis is rejected and vice versa. Also, Tukey HSD Post Hoc Multiple Comparison Test has been used to check each value that gets less than 0.05; this is illustrated in detail in Chapter 9.

6.4.4.4 Sub-task: Data Reduction and clustering

In chapter 10, the researcher reduced the number of factors to 44 end user factors. This has been achieved through using factor analysis as well as the redundant data. Also the correlation method has been used to find the biggest effective factors in each component. Then the factors were selected and distributed based on their relation to the ATTs as well as based on their given code. After that, the reliability of each cluster was tested through using the testing reliability of grouping EUFs in each group separately. Reliability testing is through using Cronbach's alpha: if Cronbach's alpha is more than .5 this means it is acceptable. If it is lower than .5 this means it is unacceptable.

6.4.5 Task 5: UCPBD assessment tool

Achieving an assessment tool at this stage includes two sub-tasks, which are development of an assessment tool and testing the assessment tool; these sub-tasks will be explained in the following sections.

6.4.5.1 Sub-Task: Development of an UCPBD assessment tool

To develop this tool, some assessment tools such as BREEAM, LEED, DGNB Label, GREEN STAR and CASBEE were reviewed in order to check their criteria and compare them with UCPBD assessment tool criteria. Then, the way of certification for the tool was checked through points then through percentages. After that, the design tool indicators were looked at from scoring and methods, then the equation that has been used, in order to calculate the design achievement. After these reviews, the method of scoring the UCPBD assessment tool was developed. Then, it was involved in the weighting of each end user, based on the correlation between components with end user factors. Then the two calculation methods that assess the scores of the architects were identified; the first calculation without considering weighting and the second calculation with considering the weight of end user factors, as shown in Chapter 11.

6.4.5.2 Sub-Task: Testing the tool

The second part of the assessment of the tool is testing the tool. This tool has been tested based on four projects which are namely Houghton Street Project, Cherry Mill Project, Fitzroy Street Project and Tullis Russell Environmental Education (TREE) Centre. Each one of these project has been scored by the designer. Then, it has been calculated with and without considering the weighting, as shown in the bottom of each assessment sheet in Chapter 11.

6.4.6 Task 6: Discussion and Conclusion Chapter

Chapter 12 discusses the research questions to check if it they match the questions of research as well as the objectives. It will discuss each question by looking at several topics: architectural design theories, conceptual model, PDHAs, the end user factors, the data analysis, and the assessment tool.

Chapter 12 provides the conclusion of the research, its main contribution, suggestions for future work and the limitations of this study.

6.5 Summary of this Chapter

This chapter has included the research methods that have been followed in this research to develop the conceptual model. As has been introduced, this chapter comprises qualitative and quantitative methods. The previous chapters have used quantitative data (literature review) which was based on them developing the qualitative questionnaire. The questionnaires were delivered to the practising architects to fill in. The results of collecting the data will be introduced in the following chapters.

Chapter Seven: Findings and Descriptive Analysis

7.1 Introduction:

The previous chapter described the methodology that has been used in this research. This chapter details and describes the findings. First of all, it identifies the target group. The research question has been answered through doing the statistical analysis for the list of the design ATTs and EUFs. Then the most effective factors have been identified. The details for this analysis will be explained in the following sections.

7.2 Restatement of the Problem of the Study

The main problem in this study was to investigate the effectiveness of the EUFs on the design of PBD. The EUFs will be assessed based on the respondents' professional role and their experience.

7.3 Restatement of Research Hypotheses

The following were the hypotheses for the study:

General Architect Perception

1. A_x: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs on PBD based on their professional role.

A_y: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs on PBD based on their professional role.

2- A_x: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs on PBD based on their experience.

A_y: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs on PBD based on their experience.

Passive design human attributes:

End User factors of Passive Design Functionality:

3. A_1: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design functionality S-ATTs: site, orientation and vegetation, building form, space planning, roof and façade" based on both their professional role and experience.

A_{01}: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design functionality S-ATTs: site, orientation and vegetation, building form, space planning, roof and façade" based on both their professional role and experience.

End User factors of Passive Design Performance:

4. A_2: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design performance S-ATTs: site performance, space performance, thermal comfort performance, natural ventilation performance, day lighting performance, acoustic performance and adequacy and consumption strategies design factors".based on both their professional role and experience.

A_{02}: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design performance S-ATTs: site performance, space performance, thermal comfort performance, natural ventilation performance, day lighting performance, acoustic performance and adequacy and consumption strategies design factors" based on both their professional role and experience.

End User factors of Passive Design Usability:

5. A_3: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design usability S-ATTs: operability and human behaviour design factors" based on both their professional role and experience.

A_{03}: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design usability S-ATTs: operability and human behaviour design factors" based on both their professional role and experience.

End User factors of Passive Design Flexibility:

6. A_4: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design flexibility S-ATTs: future adaptability and flexible space" based on both their professional role and experience.

A_{04}: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design flexibility S-ATTs: future adaptability and flexible space" based on both their professional role and experience.

End User factors of Passive Design Reliability:

7. A_5: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design reliability S-ATTs: durability, material reliability and resilient design factors" based on both their professional role and experience.

A_{05}: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design reliability S-ATTs: durability, material reliability and resilient design factors" based on both their professional role and experience.

End User factors of Passive Design Maintainability:

8. A_6: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design maintainability S-ATTs: standardisation, material and accessibility design factors" based on both their professional role and experience.

A_{06}: There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design maintainability S-ATTs: standardisation, material and accessibility design factors" based on both their professional role and experience.

Current practice:

Integration of End User factors of Passive Design Functionality:

9. B_1: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF.

B_{01}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF.

Integration of End User factors of Passive Design Performance:

10. B_2: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDP.

B_{02}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDP.

Integration of End User factors of Passive Design Usability:

11. B_3: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDU.

B_{03}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF.

Integration of End User factors of Passive Design Flexibility:

12. B_4: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDFL.

B_{04}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF.

Integration of End User factors of Passive Design Reliability:

13. B_5: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDR.

B_{05}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDR.

Integration of End User factors of Passive Design Maintainability:

14. B_5: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDM.

B_{05}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF.

7.4 Descriptions of Participants' Information

This part of the questionnaire included six questions. The first question, which requested the respondent's name, was optional, the second questions requested contact details, the third question asked for details about the company and institute to which the respondents were affiliated. The fourth question was about the professional role of the architects. The fifth question was about the experience of the architects. The final question was whether they wanted to receive the research results or not. In this survey, the author paid attention to the last three questions, as will be introduced in the next sections.

7.4.1 Professional role

The findings of the professional role question are shown in Table 7-1, where the respondents are classified based on their professional role. The finding was as follows: 29 (26.4%) practising architects, 49 (44.5%) academic and practising architects and 32 (29.1%) academic architects. The total number of respondents in this study is 110. In Table 7-1, it appears that the largest sample was for academic and practising architects which equalled 44.5%.

1-Practising Architects		2-Academic and Practising Architects		3-Academic Architect		Total	
No	Percentage	No	Percentage	No	Percentage	No	Percentage
29	26.4%	49	44.5%	32	29.1%	110	100%

Table 7-1: The Professional role

7.4.2 Respondents' Years of Experience

The researcher considers experience as an important requirement in order to compare the respondents' interests and to find out how they prioritise EUFs. The respondents' experience is illustrated in Table 7-2.

Years of Experience							
0-5 Years		5-10 Years		More than 10 Years		Total	
No	Percentage	No	Percentage	No	Percentage	No	Percentage
33	30%	23	20.9%	54	49.1%	110	100%

Table 7-2: Years of experience

As illustrated in Table 7-2, 53 (49.1%) of respondents have more than 10 years' experience, 23 (20.9%) of the architects have between 5 and 10 years' experience, and 33 (30%) of architects have between 0 to 5 years' experience. This will be considered by the author to investigate how different types of experience can reflect on assessment of EUFs.

7.4.3 Receiving a Copy of the Result

All respondents were asked whether they wanted to receive a copy of the result or not. In case they did, they were asked to provide their contact details. The finding shows that 84 (76.4%) respondents are interested to receive a copy of the result. However, 26 (23.6%) respondents are not interested to receive a copy of the result, as illustrated in Table 7-3. The group who preferred to receive a copy of the result will be contacted by the author when the data analysis is finalised.

The percentage of the respondents who are interested in receiving a copy of the result					
Yes		No		Total	
No	Percentage	No	Percentage	No	Percentage
84	76.4%	26	23.6%	110	100%

Table 7-3: The percentage of the respondents who are interested in receiving a copy of the results

7.5 Questionnaire analysis

7.5.1 First part of the questionnaire: Passive design Human Attributes

7.5.1.1 Passive Design Functionality

Table 7-4 illustrates the respondents' scores for each EUF of the PDF. This attribute of UCPBD comprises forty-three EUFs. Table 7-4 shows the number of respondents in each score for each EUF. It highlights the most effective EUFs and the least effective EUFs from the analysis of these sections. The mean effectiveness for the "Orient the building for optimum lighting, ventilation and thermal comfort" end user factor is 4.51 and has a S.D. of .896. This suggests very good agreement between respondents on the level of the effectiveness of this measure. The majority of the respondents believe that this EUF has an obvious effectiveness of score 5 (very effective). This is clear from the respondents' mass in this score, as shown in Table 7-4. This aligns with the trend of various authors as introduced in the literature review, such as Fernandez-Gonzalez (2007). He designed the largest elevation in the north and south to reduce the thermal transmittance, on the one hand. On the other hand, this was also to increase the benefit for the solar which of course to collect from the test cell. Appendix D – Table D1 shows their percentages and histogram.

The distribution of the effectiveness of the "Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort" EUF is illustrated in Appendix D and Table 7-4. The scores are from 1 - 'very ineffective' - to 5 – 'very effective'. The mean value is 4.31, and has a standard deviation of it .875. This is a clear indicator that there is a good agreement among the participants. Of course, there are various authors who have concentrated on this strategy. The shading devices can play a clear role in optimising lighting, heating and ventilation of the space. Appreciation of shading devices should be accurate based on their orientation and compliance with site circumstances (Ministry for the Environment, 2008). There is an agreement between the literature review and participants' perspectives.

The EUF "Orient openings to facilitate natural ventilation", with a mean value 4.26 and S.D. of .809, has been chosen as an essential factor by the architects. This standard deviation had shown the level of agreement between the designers. In this questionnaire, 48 architects gave a score of 5, and 48 gave a score of 4 for this EUF. 96 (97.2%) designers considered this EUF as an effective EUF, as shown in Table 7-4 and Appendix D- Table D6. The effective of this factor is agreed also by several authors as identified from the literature review. BIM (2011) and Ahsan (2009) referred to the importance of location and selection of openings and how they can effect optimisation of the air flow as well as cross-ventilation through the space.

The “Plan specific spaces or functions to coincide with solar orientation” end user factor carried a mean value of 4.25 and S. D. of .756, and was considered as an effective factor, as it is provided on survey data in Table 7-4 and Appendix D-Table D10. Milne, Liggett, Benson, and Bhattacharya (2008) confirm this: that the floor plan should be organised in such a way to coincide with solar orientation. The effectiveness of this EUF appeared on mass respondents in both effective and very effective EUFs. 46 individuals gave this EUF a score of 5, 47 a score of 4, 15 a score of 3, and 2 a score of 2, as shown in Table 7-4. 93 respondents out of 110 (84.5%) scored it as an essential EUF in UCPBD.

The “Provide high levels of insulation in the façade and building envelope to reduce summer conductive gain and to preserve internal heat” EUF, with the mean value 4.2 and S.D.=.833, was selected as an effective EUF of UCPBD. The survey results show that 45 individuals allocated a score of 5, 48 a score of 4, 11 a score 3 and 6 a score for 2 to this EUF. 93 respondents out of 110 (84.5%) believe that this EUF is an effective EUF, while 11 individuals (10.0%) believe it is a possible EUF, as illustrated in Table 7-4 and Appendix D-Table D7. The percentage of respondents who agree this EUF is an effective EUF is predictable. For this reason, the Building and Construction Authority (2010) referred to the importance of insulation and how it can optimise heating.

The distribution of the effectiveness of the “Design plan to create buffer zones from the summer radiation” EUF is 4.18 and it has a S.D. of .706. This suggests good agreement between respondents on the level of the effectiveness of this measure. The majority of the respondents believe that this factor has an obvious effectiveness of score 4 (effective) and 5 (very effective). This is clear in the respondents’ mass in this score, as shown in Table 7-4. Also, it is shown in their percentage in Table 7-4 and Appendix D-Table D3. Ip and Miller (2006) explained a case study from Brighton and how the sunspaces can provide both sunlight and thermal comfort. The importance of considering the distribution plans is reflecting and matching what respondents said.

“Use skylight, light tube and clerestory for natural illumination” has the mean value of 4.18 and S. D. of .744. The standard deviation of the questionnaire presents good agreement among the participations. 39 participations gave a score of 5 and 55 gave a score of 4. 94, indicating that they accept that this is an effective EUF. The majority of respondents had the scores 4 and 5, which reflects that they gave a score more than neutral as illustrated in Appendix D and Table 7-4. The National Domelight Company (2009) indicated the role of skylights in optimising day lighting.

Another EUF, “Use central atriums, courtyards and lobbies (elevators, and stairs can be locate in central areas) for optimum ventilation”, has the mean value of 4.15 and S. D. of .822. There is very good agreement between the designers regarding this EUF. This result is expected, as the Ministry for the Environment (2008) considered central atriums to be one of the solutions to optimise ventilation. This factor is selected by the architects as one of the effective EUFs. A total of 39 of the architects gave a score of 5 and 53 a score 4 to this EUF. In total, this EUF was selected as effective by 92 (83.7%) respondents, as illustrated in Appendix D and Table 7-4.

From 110 designers, 39 gave a score of 5 and 48 a score of 4 to the EUF "Shape the building to maximise exposure to [winter sun and summer breezes]". 78 out of 110 believe that this EUF is an effective and very effective EUF. Finally, the mean value of this EUF is 4.06 and its S.D is .921. This result referred to the need to consider this EUF as one of the most effective EUFs in UCPBD as there is a strong agreement between designers regarding it. For example, Prom et al (1989) concentrate on building geometry and how it can be effective in PDF.

"Provide vertical air shafts/stacks, and central exhaust paths to promote interior airflow": this factor's effect on UCPBD was scored by the architects as follows: 35 out of 110 gave it a score of 5, 53 a score of 4, 17 a score of 3, 3 a score of 2 and 2 a score of 1. 88 respondents (80%) chose this EUF as an effective EUF. The result of this survey presents the mean value of the EUF as 4.05 and S.D.=.866. The majority of the respondents agreed on the effective and very effective scores, which means this is an essential EUF that needs to be considered. The United States Department of Energy (2000) referred to how the central exhaust can affect promotion of interior air flow. This strategy has been selected as one of the most effective EUFs by the respondents. These factors are listed as a hierarchy descending based on their effectiveness.

However, the least effective EUFs are listed in hierarchical ascending order as follows. 8 architects out of 110 (7.3%) gave a score of 5, 32 (29.1%) a score of 4, and 34 (30.9%) a score of 3 for "using low mass construction to allow rapid heat-up or cooling of structure" EUF. Looking at the mean value of 3.03 and S.D. of 1.079, this factor can be seen to be considered effective. Overall, 34 respondents considered it to be an effective EUF. There is agreement shown between the respondents. The results are illustrated as a histogram and normal curve in Appendix D and Table 7-4.

The "Narrow floor width to optimise natural ventilation" EUF with the mean value of 3.46 and S. D. of 0.964 was chosen as an effective EUF in this survey. 16 respondents gave it a score of 5, 39 a score of 4 and 36 a score of 3. 55 respondents out of 110 (50%) agreed on selecting this EUF as an effective EUF, whereas 36 of them (32.7%) agreed to accept it as a possible EUF. In Table 7-4, the majority of the respondents were concentrated between 3 and 4 scores. Agreement to accept it as a EUF appeared in score 4, as shown in Appendix D and Table 7-4. The Ministry for the Environment (2008) said the narrow floor can have an affect on maximising ventilation.

The mean value of the "The proportion of the plan is long and narrow (use linear plan form, or a similar strategy) to optimise day lighting" end user factor is 3.48 and .965 for S.D., which are also proof of its acceptance. In this survey, 19 designers gave a score of 5, 32 a score of 4 and 43 a score of 3; and the histogram of this factor is shown in Appendix D-Table D3. The Ministry for the Environment (1998-2011) clarified the relationship between the area and shape of the plan and day lighting function. However, the respondents ranked it as one of the lowest effective EUFs.

From 110 designers, 14 gave a score 5 and 48 a score of 4 to the “Minimise openings in envelope to reduce thermal gain” end user factor. 62 out 110 believe that this EUF is an effective and very effective EUF. Finally, the mean value of this EUF is 3.52 and its S.D is .946. This result referred to the need to consider it as one of the effective EUFs in UCPBD, as shown in Table 7-4 and Appendix D-Table D6. The United States Department of Energy (2000) indicated how façade openings can affect thermal comfort. The designers have not paid attention to this EUF.

The mean effectiveness for the “Minimise the ratio of exterior surfaces to interior floor areas” end user factor is (3.58) and it has a standard deviation of (.828). This indicates good agreement between respondents regarding the effectiveness. Frequencies of responses show that 10 architects (10.9%) gave a score of 5, 51 (46.4%) a score of 4, 37 (33.6%) a score of 3, 9 (8.2%) a score of 2, and 1(.9%) a score of 5 to this end user factor. The fact that the higher score has gained more than the neutral one shows that the architects recognised this factor as an effective factor which could play an essential role in user centred passive building design. An S.D of .828 indicates the level of agreement between the architects regarding this factor. Finally, the histogram and normal curve of this factor is illustrated in Appendix D-Table D5. Several authors such as BIM (2011) and Ahsan (2009) concentrate on the relationship between the proportion of both glass area and floor plan area. The designers gave it one of the lowest factors. However, it still can be accepted as an effective factor.

The mean effectiveness of the “Attenuate plan to promote ventilation” end user factor is 3.61 and it has a standard deviation of .939. For this factor, 20 designers selected a score of 5, 40 a score of 4, 39 a score of 3, 9 a score of 2 and 2 a score of 1. The outcome of this survey is that 60 architects (54.6%) assumed that this factor is an effective factor that should be involved in user centred passive building design; and 39 architects (35.5%) accepted it as a possible factor. The finding for this factor is summarised in Appendix D-Table D4. The Ministry for the Environment (2008) referred to how attenuating the plan is important to maximise ventilation. This reflects the designers’ rankings. It is still acceptable.

The “Use higher window to wall area ratios to maximise solar access and ventilation” end user factor with a mean value 3.64 and S.D. of .864 has been chosen as an essential factor by the architects. This standard deviation shows the level of agreement between the designers. In this questionnaire, 14 architects gave a score of 5 and 55 gave a score of 4 for this factor. 69 (62.7%) designers considered this factor as an effective factor in Table 7-4 and Appendix D-Table D7. Ihm (2009) clarified how the size of the window can affect the amount of lighting on the space. The designers considered it as a demand factor. The respondents selected it as one of the lowest effective end user factors.

The “Subdivide interior to create separate heating and cooling zones” end user factor is one of the most effective factors. Its mean value is 3.64 and its D.V=.993 in the survey. 18 respondents have given it a score 5, 53 a score of 4, 24 a score of 3, 11 a score of 2 and 4 a score of 1. 71 respondents look to this factor as an effective factor, as illustrated in Appendix D-Table D2. From the result of the D.V=.993, there is obviously a very good agreement between the respondents. The Ministry for the Environment (2008) and the Department of Education, Northern Ireland (DENI) and corpcreator (1998) agreed about the effectiveness of subdividing the spaces on passive design strategies functions.

The “Use exterior elements to direct summer wind flow into the interior” end user factor’s effect on user centred passive building design was scored by the architects as follows: 17 of 110 gave a score of 5, 52 a score of 4, 28 a score of 3, 12 a score of 2 and 1 a score of 1. 69 respondents (62.8%) chose this factor as an effective factor. The result of this survey presents the mean value of the factor as 3.65 and the S.D.=.903. The majority of the respondents agreed on the effective and very effective scores, which means that exterior elements are an essential factor, as shown in Appendix D-Table D7. BIM (2011) and Ashan (2009) refered to direct the natural sources to the interior space.

The distribution of the effectiveness of the “Use open plan interior to promote interior airflow” end user factor is 3.65 and has a S.D. of .913. This suggests good agreement between respondents on the level of the effectiveness of this measure. The majority of the respondents believe that this factor has an obvious effectiveness of score 4 (effective) and 5 (very effective). This is clear in the respondents’ mass in this score, as shown in Table 7-4. The means of the rest factors are between 3.65 and 4.05. However, all of them are more than neutral, so they could be considered as effectiveness factors. Lev-el (The authority of sustainable building) (2011) indicated that open plan can lead to maximising ventilation. However, it is placed on the lowest rank.

Code	End User factors of Passive Design Functionality	Total Number	Frequency of scores					Mean	Std. De-viation	Ranking
			1	2	3	4	5			
AA1	Use vegetation for optimum lighting, ventilation and thermal comfort	110	3	6	25	50	26	3.82	.950	25
AA2	Orient the building for optimum lighting, ventilation and thermal comfort	110	3	2	6	24	75	4.51	.896	1
AA3	Use nearby landforms and structures for wind protection and summer shading	110	2	8	17	50	33	3.95	.956	14
AB1	Design compact building form for optimum heating and ventilation	110	4	6	25	51	24	3.77	.974	27
AB2	Use low mass construction to allow rapid heat-up or cooling of structure	110	9	27	34	32	8	3.03	1.079	43
AB3	Shape the building to maximise exposure to [winter sun and summer breezes]	110	2	5	16	48	39	4.06	.921	9
AB4	Use high mass construction with appropriate insulation to promote night ventilation	110	2	10	23	54	21	3.75	.933	30
AC1	Subdivide interior to create separate heating and cooling zones	110	4	11	24	53	18	3.64	.993	36
AC2	Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	110	1	8	27	54	20	3.76	.867	28
AC3	Use central atriums, courtyards and lobbies (elevators, and stairs can be locate in central areas) for optimum ventilation	110	2	1	15	53	39	4.15	.822	8
AC4	Provide vertical air shafts/stacks, and central exhaust paths to promote interior airflow	110	2	3	17	53	35	4.05	.866	10
AC5	Use open plan interior to promote interior airflow	110	2	8	35	46	19	3.65	.913	34
AC6	The proportion of the plan is long and narrow (use linear plan form, or a similar strategy) to optimise day lighting	110	1	15	43	32	19	3.48	.965	41
AC7	Organise rooms, corridors, stairwells in a way that uploads a low resistance airflow path through the building	110	0	7	33	54	16	3.72	.791	32
AC8	Consider interior surface colours and finishes for optimum day lighting	110	0	10	16	54	30	3.95	.887	13
AC9	Design plan to create buffer zones from the summer radiation	110	0	1	16	55	38	4.18	.706	6
AC10	Plan specific spaces or functions to coincide with solar orientation	110	0	2	15	47	46	4.25	.756	4
AC11	Narrow floor width to optimise natural ventilation	110	1	18	36	39	16	3.46	.964	42
AC12	Provide solar-oriented interior zone to store and maximise solar heat gain	110	1	8	23	58	20	3.80	.855	26
AC13	Attenuate plan to promote ventilation	110	2	9	39	40	20	3.61	.939	38
AC14	Link the exterior and interior airflows by single-sided, cross or stack ventilation	110	0	10	19	61	20	3.83	.833	24
AD1	Use roof elements for stack effect ventilation	110	0	3	20	64	23	3.97	.710	12
AD2	Use skylight, light tube and clerestory for natural illumination	110	0	3	13	55	39	4.18	.744	7
AD3	Use solar roof collectors on the south-oriented surfaces	110	0	9	18	47	36	4.00	.909	11
AD4	Use double roof and wall construction for ventilation within envelope	110	0	9	36	42	23	3.72	.890	31
AD5	Use ventilated roof to lower summer gains through roof	110	0	7	21	54	28	3.94	.838	15
AD6	Use of an appropriate shape and angle of the roof for optimum ventilation and thermal comfort	110	2	7	20	52	29	3.90	.928	18
AE1	Minimise the ratio of exterior surfaces to interior floor areas	110	1	9	37	51	12	3.58	.828	39
AE2	Use high-capacitance materials to store solar heat gain and control heat flow through envelope	110	0	7	18	61	24	3.93	.798	17
AE3	Optimise south-facing glazing	110	1	5	25	49	30	3.93	.875	16
AE4	Use Trombe wall or double façade to collect solar gain	110	3	8	24	53	22	3.75	.950	29
AE5	Locate thermal mass inside the envelope to store heating	110	0	7	21	66	16	3.83	.752	23

AE6	Minimise openings in envelope to reduce thermal gain	110	2	15	31	48	14	3.52	.946	40
AE7	Use solar wall on south-oriented surfaces	110	0	7	19	62	22	3.90	.789	20
AE8	Develop details to minimise air infiltration and ex-filtration	110	2	8	28	37	35	3.86	1.009	21
AE9	Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort	110	1	4	12	36	57	4.31	.875	2
AE10	Use louvred wall for maximum ventilation control	110	1	8	35	46	20	3.69	.886	33
AE11	Use exterior elements to direct summer wind flow into the interior	110	1	12	28	52	17	3.65	.903	35
AE12	Orient openings to facilitate natural ventilation	110	1	3	10	48	48	4.26	.809	3
AE13	Details openings to limit undesired air infiltration and ex-filtration as well as to reduce convective gains	110	2	6	22	58	22	3.84	.873	22
AE14	Provide light shelves to allow daylight to penetrate deep into a building	110	1	4	23	59	23	3.90	.801	19
AE15	Use higher window to wall area ratios to maximise solar access and ventilation	110	1	11	29	55	14	3.64	.864	37
AE16	Provide high levels of insulation in the façade and building envelope to reduce summer conductive gain and to preserve internal heat	110	0	6	11	48	45	4.20	.833	5

Table 7-4: Descriptive Information of the First Part of the Questionnaire Survey: Passive Design Functionality

7.5.1.2 Passive Design Performance

Table 7.5 illustrates the effectiveness of passive design performance EUFs. This ATT includes twenty-seven EUFs. The mean effectiveness for the “A comfortable internal air temperature” EUF is 4.49 and it has a standard deviation of 0.632, which indicates very good agreement between designers on the effectiveness of this driver. The majority of the respondents are concentrated at score 5, which is the very effectiveness EUF, as shown in Table 7-5 and Appendix E-Table E2. Fowler et al (2005) and Gossauer and Wagner (2007) referred to the need to design spaces that can cope with user needs. This agrees with the respondents’ result.

The distribution of effectiveness of the “The adequacy of natural light in spaces” EUF is illustrated in Table 7-5. The effectiveness ranges from 1 very ineffective and 5 very effective. The mean value is 4.36 and the standard deviation is .787, which shows that there is a good agreement about the effectiveness of this EUF among the designers. The agreement is expected as various authors have concentrated on this EUF, as follows: Fowler et al (2005), Cutler and Kane (2009) and Todd (2001).

The “Utilizing views and orientation” EUF with a mean value 4.34 and S.D. of .694 has been chosen as an essential EUF by the architects. This standard deviation shows the level of agreement between the designers. In this questionnaire, 49 architects gave a score of 5 and 51 gave a score of 4 for this EUF. 100 (90.9%) designers considered this factor as an effective EUF in Table 7-5 and Appendix E-Table E1. As introduced in the literature review, Dunne et al (2011) indicated that a building’s view and orientation should be considered.

The “The air quality in space enhances or interferes with well-being of occupants” EUF carrying a mean value of 4.33 and S. D. of .679 was considered as an effective EUF as is provided in the survey data in Appendix E-Table E2. Fowler et al (2005) referred to how the air quality can affect a building’s occupants.

48 individuals gave a score of 5 and 51 a score of 4 for this EUF, as shown in Table 7-5. 99 respondents out of 110 (90%) selected it as an essential EUF in UCPBD. The “The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)” EUF with the mean value of 4.31 and S.D.=.726 was selected as an effective EUF of UCPBD. Fowler et al (2005) and Todd (2001) focused on air quality in the spaces. The result reflects the effectiveness of this EUF and matches the literature review. The

survey results show that 47 individuals allocated a score of 5 and 53 a score of 4 to this EUF. 100 respondents out of 110 (90.9%) believe that this EUF is an effective EUF, as in Appendix E-Table E3.

The previous five EUFs are the highest EUFs that were selected by the participations. The lowest lowest scores will now be described. The “Utility passive design cores uniformly designed and vertically stacked” EUF is accepted as an effective EUF by the respondents. The mean value of 3.55 and .808 of S.D. are also proof of its acceptance. In this survey, 12 designers gave a score of 5, 45 a score of 4, 47 a score of 3, 4 a score of 2 and 2 a score 1 to this factor. Appendix E-Table E4 presents a histogram including normal distribution curve. The Centre for the Built Environment (2011) focused on the vertical unity core. This could help the design function to perform without any barrier.

The mean value of “The horizontal utility systems of passive building logically configured to serve multi-user needs” is 3.57 and the S.D. is .872, showing that it has been chosen as an essential EUF by the architects. In this questionnaire, 15 architects gave a score of 5, 43 gave a score of 4, 45 gave a score of 3, 4 gave a score of 2 and 3 gave a score of 1 for this EUF. 58 (52.7%) designers considered this EUF as an effective EUF. Also, the standard deviation shows very good agreement between the architect respondents, as shown in Appendix E-Table E4.

The “Make the atrium or rotunda adequate for cleaning, maintenance etc” EUF was selected as an effective EUF. This is according to the respondents’ scores. Before referring to the scores, the mean value of this EUF is 3.65 and S.D is equal .83. 16 respondents out of 110 gave a score of 5 and 47 a score of 4 for this EUF. This EUF is accepted as an essential EUF by 63 respondents (57.2%). The finding is illustrated in Table 7-5 and in Appendix E-Table E4. There is a good agreement among the respondents based on standard deviation result, even though; this EUF was selected based on the literature review as refrred by Khalil and Husin (2009).

19 of the architects gave a score of 5, 46 a score of 4, 40 a score of 3 and 5 a score of 2 to the “Atrium or rotunda control devices for optimum space comfort” EUF. The finding of the survey illustrates that this EUF was selected as an effective EUF by 65 respondents (59.1%). This finding has a mean value of 3.76 and S.D.= .803 in Table 7-5, which shows the different views of the participants. The majority of the score has been given to the score of 4 as the histogram shows in Appendix E-Table E3. Khalil and Husin (2009) indicated the atrium and rotunda should be controlled to optimise lighting to make the space comfortable for the EU.

The “Enhancement of site to consider identity” EUF is one of the most effective factors, giving a mean value of 3.75 and S.D. of .88, which proves that this EUF gained a level of agreement by architects. The survey shows that 25 respondents out of 110 gave a score of 5 and 40 a score of 4 to this EUF from their perspective. 65 respondents (59.1%) accepted this EUF as an effective EUF for UCPBD. Dunne et al (2011) stated that the site should respect identity; the designers have not paid attention to this EUF in their responses. The standard deviation shows a good agreement between the participants regarding the effectiveness of this EUF. This EUF is relevant to the space planning S-ATT, as shown in Appendix E-table E1.

Code	End User factors of passive Design Performance	Total Number	Frequency of scores					Mean	Std. Deviation	Ranking
			1	2	3	4	5			
BA1	Utilizing views and orientation	110	0	2	8	51	49	4.34	.694	3
BA2	Affect site on visual focus	110	0	4	36	43	27	3.85	.837	21
BA3	Enhancement of site to consider identity	110	0	7	38	40	25	3.75	.880	23
BB1	Durable, high quality finishes	110	0	6	23	48	33	3.98	.857	14
BB2	Select good colour to use	110	0	7	21	55	27	3.93	.832	16
BB3	Passive spaces layout allow social interaction	110	0	6	23	54	27	3.93	.821	17
BB4	Provide a special character for the space based on building type	110	1	9	29	47	24	3.76	.918	22
BB5	Space layout allows for security, way finding, and flexibility of use	110	2	6	22	47	33	3.94	.941	15
BB6	Space layout enhances or interferes with well-being of occupants	110	1	4	32	45	28	3.86	.872	20
BB7	The adequacy of passive design space available for function/activities	110	0	7	22	58	23	3.88	.810	19
BC1	The temperature controls provide for the needs of different occupants	110	0	6	10	60	34	4.11	.782	12
BC2	Thermal comfort in spaces enhances or interferes with well-being of occupants	110	0	3	22	47	38	4.09	.808	13
BD1	A comfortable internal air temperature	110	0	1	5	43	61	4.49	.632	1
BD2	The air quality in space enhances or interferes with well-being of occupants	110	0	1	10	51	48	4.33	.679	4
BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)	110	1	1	8	53	47	4.31	.726	5
BE1	The adequacy of light sufficiency in spaces	110	0	3	12	55	40	4.20	.739	8
BE2	The adequacy of natural light in spaces	110	0	4	9	40	57	4.36	.787	2
BE3	The visual comfort of the lighting (e.g., glare, reflections, contrast)	110	0	3	10	52	45	4.26	.738	6
BE4	The lighting quality enhances or interferes with well-being of occupants	110	0	4	20	43	43	4.14	.840	11
BE5	Atrium or rotunda control devices for optimum space comfort	110	0	5	40	46	19	3.72	.803	24
BF1	Select insulation against noises from corridors to give space privacy	110	0	6	12	51	41	4.15	.826	9
BF2	Utilize good acoustic conditions	110	0	4	17	48	41	4.15	.811	10
BG1	The horizontal utility systems of passive building logically configured to serve multi-user needs	110	3	4	45	43	15	3.57	.872	26
BG2	Utility passive design cores uniformly designed and vertically stacked	110	2	4	47	45	12	3.55	.808	27
BG3	Make the atrium or rotunda adequate for cleaning, maintenance etc	110	1	6	40	47	16	3.65	.830	25
BG4	Reduce consumption of water, energy and electricity	110	1	1	18	42	48	4.23	.820	7
BG5	Response time to urgent repair issues	110	2	2	27	53	26	3.90	.845	18

Table 7-5: Descriptive Information of the First Part of the Questionnaire Survey: Passive Design Performance

7.5.1.3 Passive Design Usability

The PDU ATT consists of twelve EUFs. Table 7-6 provides the number of respondents for each EUF. The mean effectiveness for the “Space to provide multi-user comfort (light, fresh air, optimal temperature)” EUF is 4.26 and it has a standard deviation of .762. This indicates good agreement between the respondents on the level of effectiveness of this EUF. This result is expected because this EUF has been selected based on the literature review. This EUF is highlighted by Brown et al (2010). The majority of the respondents think that this EUF is “effective”, which is score 4, as shown in Table 7-6 and in the histogram curve in Appendix F-Table F2.

The allocation of effectiveness of the “Consider safety, health and physical well-being needs for multiple users of passive buildings” EUF is also displayed in Table 7-6 and Appendix F. The effectiveness score ranges from 1 to 5. The mean value is 4.22 and it has a standard deviation of .783. This result proves that there is a good agreement between the respondents about the effectiveness of this EUF. The result for this EUF matches the interests of several authors, as follows: Mitchell (2011), Brown et al (2010), Haron and Hamad (2011) and Hansen et al (2005).

The “Incorporate passive design technologies which are easy to operate by multiple users” EUF was distinguished as an effective EUF, which presents a mean value of 4.08 and S.D of .836 in this finding. 37 designers selected a score of 5, 50 a score of 4, 19 a score of 3, 3 a score of 2 and 1 a score of 1 for this EUF. For the outcome of this survey, 87 architects (79.1%) assumed this EUF is an effective EUF that should be included in UCPBD; and 19 architects (17.3%) accepted it as a possible EUF.

The finding for this EUF is summarised in Appendix F-Table F2. Nylåna (2005) and Brown and Cole (2009) referred to the importance of providing technologies that cope with end user demands.

The “Avoid slopes and steps of passive space floors” EUF is one of the most effective EUFs, giving a mean value of 3.28 and S.D. of .879, which proves that this EUF gained a high level of agreement among architects. The survey shows that 8 respondents out of 110 gave a score of 5, 34 a score of 4, 53 a score of 3, 11 a score of 2 and 4 a score of 1 to this EUF from their perspective. 42 respondents (38.2%) accepted this EUF as an effective EUF for UCPBD; and 53 respondents (48.2%) accepted it as a potential EUF. This EUF is relevant to the space planning S-ATT in Appendix F-Table F1. Even though this EUF can effect on EU safety as Mitchell (2011) claimed. The respondents paid little attention but it is still an effective factor.

The “Group homogeneous passive functions together for efficient operability” EUF with the mean value of 3.66 and S. D. of .87 was chosen as an effective EUF in this survey. 15 respondents gave a score of 5, 55 a score of 4, 30 a score of 3, 8 a score of 2 and 2 a score of 1 to this EUF. 70 respondents out of 110 (63.6%) agreed in selecting this EUF as an effective EUF, whereas 30 of them (27.3%) agreed to accept it as a possible EUF. In Appendix F-Table F1 the histogram curve shows that the majority of the respondents concentrate on 3 and 4 scores. Their agreement to accept it as a EUF appears in the score 4. This result is not expected because the design functions should be provided with high efficiency. Several authors mentioned this EUF, as follows: Nylåna (2005), Jensø (2011) and Brown and Cole (2009).

The distribution of effectiveness of the “Optimum position of service and passive element or equipment for operability” EUF is illustrated in Table 7-6. This EUF was selected based on Lund’s (2001) reference. Optimising the position can help the EU to function as required. However, the result shows this EUF is one of the least effective EUFs in this ATT. The effectiveness ranges from 1 very ineffective to 5 very effective. The mean value is 3.76 and the standard deviation is .823, which shows that there is an agreement among the designers about the effectiveness of this EUF.

Code	End User factors of passive Design Usability	Total Number	Frequency of scores					Mean	Std. Deviation	Ranking
			1	2	3	4	5			
CA1	Optimum position of service and passive element or equipment for operability	110	2	3	32	55	18	3.76	.823	10
CA2	Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	110	1	3	23	58	25	3.94	.793	8
CA3	Group homogeneous passive functions together for efficient operability	110	2	8	30	55	15	3.66	.870	11
CA4	Avoid slopes and steps of passive space floors	110	4	11	53	34	8	3.28	.879	12
CA5	Incorporate passive design technologies which are easy to operate by multiple users	110	1	3	19	50	37	4.08	.836	3
CA6	Accessible passive design controls for multiple users	110	1	3	24	54	28	3.95	.817	7
CA7	Design passive space that is well-suited for multi-user activities and capabilities	110	0	3	22	50	35	4.06	.793	5
CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)	110	1	1	12	50	46	4.26	.762	1
CB1	Reduce user stress and feelings of frustration due to lack of space	110	2	3	21	44	40	4.06	.911	4
CB2	Consider safety, health and physical well-being needs for multiple users of passive buildings	110	0	3	15	47	45	4.22	.783	2
CB3	Consider different sensing, smelling, hearing, feeling and seeing of users in passive space design	110	0	10	22	50	28	3.87	.900	9
CB4	Consider users’ cultural image, identity, lifestyle, psychological needs and perceptions in line with passive lighting, ventilation and thermal comfort strategies	110	1	3	25	43	38	4.04	.877	6

Table 7-6: Descriptive Information of the First Part of the Questionnaire Survey: Passive Design Usability

7.5.1.4 Passive Design Flexibility

The PDFL ATT consists of twelve EUFs. Table 7-7 provides the number of the respondents for each EUF. The mean effectiveness for the “Design passive space to respond to changes in climate conditions” end user factor is 4.07 and it has a standard deviation of .945. This indicates very good agreement between the respondents on the level of the effectiveness of this EUF. The majority of the respondents think that this EUF has an effectiveness of “very effective”, which is a score of 5, as shown in Table 7-7 and appendix G-Table G2. The respondents’ perspective matches that of Slaughter (2001). The referred to space should be adaptable to climate change. The allocation of effectiveness of the “Passive building structure should be upgradable for future regulations and safety procedures” end user factor is also displayed in Table 7-7 and Appendix G-Table G1. The effectiveness score is from 1 to 5. The mean value is 3.90 and it has a standard deviation of .957. This result proves that there is a good agreement between the respondents about the effectiveness of this EUF. Niklas and Bengt (2009) said the building structure should be created to cope with changes to regulations. The result has matched the effectiveness of this EUF.

The effectiveness of the “Design a passive building that responds to the increasing pressures of rapid changes in technology shifts” end user factor was distinguished as an effective factor which presents a mean value 3.87 and S.D of .920 in this finding. 26 designers selected a score of 5 and 55 a score of 4 for this EUF. In the outcome of this survey, 81 architects (73.6%) assumed this EUF as an effective EUF that should be involved in UCPBD. The finding of this EUF are summarised in Appendix G-Table G2. Niklas and Bengt (2009) and Finch (2009) paid attention to designing buildings that can accommodate changes to technology products. The “Use movable walls” factor is one of the most effective EUFs, giving a mean value of 3.45 and S.D. of 1.019, which proves that this EUF gained a high level of agreement from architects. The survey shows that 15 respondents out of 110 gave a score of 5 and 43 a score of 4 to this EUF from their perspective. 43 respondents accepted this EUF as an effective EUF for UCPBD. This EUF is relevant to the flexible space S-ATT, and its histogram curve is shown in Appendix G-Table G3. The respondents have not concentrated on this EUF, even though its effectiveness helps the EU change the design as they need. This EUF was chosen from the reference by Till and Schneider (2006).

The “Use modular passive space planning strategies” EUF with the mean value of 3.50 and S. D. of .926 was chosen as an effective EUF in this survey. 15 respondents gave a score of 5, 40 a score of 4, 43 a score of 3, 9 a score of 2 and 3 a score of 1 to this EUF. 65 respondents out of 110 (59.1%) agreed on selecting this factor as an EUF. In Table 7-7, the majority of the respondents are concentrated on 3 and 4 scores. Their agreeing to accept it as an EUF is obvious in the mean value result. Till and Schneider (2006) and Finch (2009) referred to the importance of modular design to help the EU easily facilitate change.

The distribution of effectiveness of the “Minimise partitions between passive spaces to control lighting, ventilation and thermal comfort” EUF is illustrated in Table 7-7. The effectiveness ranges from 1 very ineffective to 5 very effective. The mean value is 3.59 with a standard deviation of .941, which shows that there is a good agreement about the effectiveness of the EUF among the designers. The result of this EUF shows that it is one of the least effective EUFs. Moharram (1980) referred to the important of reducing the barriers and walls between spaces.

Code	End User factors of passive Design Flexibility	Total Number	Frequency of scores					Mean	Std. Deviation	Ranking
			1	2	3	4	5			
DA1	Passive building structure should be upgradable for future regulations and safety procedures	110	4	4	20	53	29	3.90	.957	2
DA2	Design passive building to adapt for dysfunctional future utilisation	110	4	4	35	47	20	3.68	.938	13
DA3	Allow ample floor-to-floor height for future modification	110	5	8	28	44	25	3.69	1.047	12
DA4	Consider the passive design that accommodates fundamental changes in user preferences	110	1	5	33	43	28	3.84	.894	7
DA5	Design the passive space to cope with changes in flow of users	110	3	2	27	53	25	3.86	.883	4
DA6	Provide horizontal and vertical circulation and spaces of passive design that encompass future expansion options	110	1	5	29	48	27	3.86	.872	5
DA7	Design a passive building that responds to the increasing pressures of rapid changes in technology shifts	110	3	5	21	55	26	3.87	.920	3
DA8	Design passive space that responds to changes in spatial dimensions (volume)	110	3	6	37	47	17	3.63	.907	15
DA9	Design passive space to respond to changes in climate conditions	110	2	3	24	37	44	4.07	.945	1
DA10	Design passive layout based on future use scenarios	110	3	7	25	51	24	3.78	.952	9
DA11	Select the passive building form for change without changing the skeleton	110	1	8	33	36	32	3.82	.969	8
DB1	Specify spaces for multiple use	110	1	8	24	51	26	3.85	.900	6
DB2	Use movable walls	110	4	16	32	43	15	3.45	1.019	18
DB3	Flexible access within and between passive spaces	110	2	9	34	48	17	3.63	.907	14
DB4	The ability to subdivide large passive design spaces	110	2	7	33	48	20	3.70	.904	11
DB5	Use modular passive space planning strategies	110	3	9	43	40	15	3.50	.926	17
DB6	Minimise partitions between passive spaces to control lighting, ventilation and thermal comfort	110	3	9	35	46	17	3.59	.941	16
DB7	Design passive space to incorporate completely new functions	110	3	4	37	43	23	3.72	.930	10

Table 7-7: Descriptive Information of the First Part of the Questionnaire Survey: Passive Design Flexibility

7.5.1.5 Passive Design Reliability

The PDR ATT consists of twelve EUFs. Table (7-8) provides the number of the respondents for each EUF. The mean effectiveness for the “Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation” EUF is 4.20 and it has a standard deviation of .822. This indicates very good agreement between the respondents on the level of the effectiveness of this EUF. The majority of the respondents think that this EUF has effectiveness EUF of “very effective”, which is indicated by respondents’ scores of 5, as shown in Table 7-8 and Appendix H-Table H1. The result for this EUF shows that the respondents selected is as the most effective EUF in this ATT. This EUF was extracted from the literature review based on ABCD (2006) and PERD (1997).

The allocation of effectiveness of the “Use high quality material with long service life to handle passive functions” EUF is also displayed in Table (7-8) and Appendix H-Table H2. This EUF was selected based on the literature review of ABCB (2006). The effectiveness score is from 1 to 5. The mean value is 4.11 and it has a standard deviation of .902. This result proves that there is a good agreement between the respondents about the effectiveness of this EUF.

The effectiveness of the “Provide optimum drainage and venting to minimise accumulation of moisture” EUF was distinguished as an effective EUF which presents a mean value 4.10 and S.D of

.741 in this finding. 34 designers selected a score of 5 and 55 a score of 4 for this EUF. For the outcome of this survey, 89 architects (80.9%) assumed this EUF to be an effective factor that should be involved in UCPBD. The findings for this EUF are summarised in Appendix H-Table H1. This EUF is one of the effectiveness factors which matches what PERD (1997) referred to: optimising the position and venting the drainage can lead to maximise a building's longevity.

The "Use standardisation of passive design elements and materials" EUF is one of the most effective EUFs, giving a mean value of 3.62 and S.D. of 1.075, which proves that this EUF gained a high level of agreement by architects. The survey shows that 24 respondents out of 110 gave a score of 5 and 41 a score of 4 to this factor from their perspective. 67 respondents accepted this EUF as an effective EUF for UCPBD. This factor is relevant to the material reliability S-ATT in Appendix H-Table H2. This EUF is selected based on ABCB (2006), which said the material should respond to the environmental changes. One of the considerations is the average expansion and contraction.

The "Passive building fabric should be adaptable to cyclic change" EUF with the mean value of 3.77 and S. D. of .885 was chosen as an effective factor in this survey. 21 respondents gave a score of 5, 54 a score of 4 and 25 a score of 3 to this EUF. 75 respondents out of 110 (68.2%) agreed in selecting this factor as an EUF. In Table 7-8, the majority of the respondents are concentrated on 3 and 4 scores. Their agreement to accept it as a EUF is shown in the standard deviation result. The result shows that this EUF is one of lowest effective EUFs. However, several authors such as PERD (1997), Balcomb (1992) and Mital et al (2007) paid attention to this EUF in one way or another. This reflects the essential nature of this EUF.

The distribution of effectiveness of the "Specify passive space strategies for user behaviour usage (such as heavy use, accidental impact and interior humidity)" EUF is illustrated in Table 7-8, as well as in the histogram curve in Appendix H-Table H2. The effectiveness ranges from 1 very ineffective to 5 very effective. The mean value is 3.62 and a standard deviation of 1.075, which shows that there is a good agreement about the effectiveness of the EUF among the designers. The result of this EUF shows that the respondents selected it as one of the least effective EUFs; this reflects the level of considering EU behaviours in designing reliability attributes, even though this EUF has been referred to by ABCB (2006).

Code	End User factors of passive Design Reliability	Total Number	Frequency of scores					Mean	Std. Deviation	Ranking
			1	2	3	4	5			
EA1	Ensure the passive performance of space or element remains serviceable	110	0	4	25	57	24	3.92	.768	9
EA2	Provide optimum drainage and venting to minimise accumulation of moisture	110	0	2	19	55	34	4.10	.741	3
EA3	Design passive service life to match user needs	110	0	5	22	57	26	3.95	.788	7
EA4	Select components that are resistant to environmental agents	110	0	1	31	43	35	4.02	.801	6
EA5	Compatibility in joining lighting, ventilation and thermal comfort elements together	110	1	3	23	48	35	4.03	.851	4
EA6	Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation	110	0	2	22	38	48	4.20	.822	1
EA7	Protect sensitive passive elements from accidental change	110	1	3	31	47	28	3.89	.850	10
EB1	Consider passive building joint seals to resist infiltration of moisture or deleterious materials	110	2	5	18	49	36	4.02	.919	5
EB2	Use high quality material with long service life to handle passive functions	110	3	1	18	47	41	4.11	.902	2
EB3	Consider the rate of expansion / contraction of material of passive design strategies	110	1	4	25	50	30	3.95	.855	8
EB4	Use standardisation of passive design elements and materials	110	5	11	29	41	24	3.62	1.075	13
EC1	Specify passive space strategies for user behaviour usage (such as heavy use, accidental impact and interior humidity)	110	4	2	28	55	21	3.79	.899	11

EC2	Passive building fabric should be adaptable to cyclic change	110		1	9	25	54	21	3.77	.885	12

Table 7-8: Descriptive Information of the First Part of the Questionnaire Survey: Passive Design Reliability

7.5.1.6 Passive Design Maintainability

The PDM ATT consists of 19 EUFs. Table 7-9 provides the number of the respondents for each EUF. The mean effectiveness for the “Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity” EUF is 4.12 and it has a standard deviation of .763. This indicates good agreement between the respondents on the level of the effectiveness of this EUF. The majority of the respondents think that this factor has an effectiveness EUF of “effective”, which respondents scored at 4, as shown in Table 7-9 and Appendix I Table-I2. This EUF is the highest effective EUF. This result matches trends mentioned by different authors as follows: Wood (2005), De Silva et al (2004), and Dunston et al (1999).

The allocation of effectiveness of the “Design for ease to adjust lighting, ventilation and thermal comfort physical element features” EUF is also displayed in Table 7-9 and Appendix I Table-I2. The effectiveness score ranges from 1 to 5. The mean value is 4.05 and it has a standard deviation of .833. This result proves that there is a good agreement between the respondents about the effectiveness of this EUF. The respondents paid attention to this EUF as per the reference from the Northumberland National Park Authority (2006).

The effectiveness of the “The interior of the PBD is designed to be easy to clean and maintain” EUF was distinguished as an effective EUF which presents a mean value of 4.03 and S.D of .818 in this finding. 31 designers selected a score of 5 and 57 a score of 4 for this EUF. In the outcome of this survey, 88 architects (80%) assumed this EUF is an effective EUF that should be involved in UCPBD. The findings of this EUF are summarised in Table 7-9 and Appendix I Table-I3. Solana et al (2005) focused on the need for accessibility in order to clean and maintain the space. They paid attention to it because they believed it is important and effective in building design.

The “Minimise use of unique materials of passive design strategies” factor is one of the most effective EUFs, giving a mean value of 3.37 and S.D. of 1.012, which proves that this factor gained a high level of agreement by architects. The survey shows that 15 respondents out of 110 gave a score of 5 and 33 a score of 4 to this EUF from their perspective. 48 respondents accepted this EUF as an effective EUF for UCPBD. It is relevant to the quality material sub-attribute, as shown in Table 7-9 and Appendix I Table-I2. This EUF is one of lowest effective EUFs for this ATT. However, Parsloe (1992), De Silva (2004) and NASA (2008) referred to the importance of considering selecting the available or local material.

The “Utilize non-destructive disassembly passive design strategies” EUF with the mean value of 3.50 and S. D. of .843 was chosen as an effective EUF in this survey. 21 respondents gave a score of 5, 42 a score of 4 and 47 a score of 3 to this EUF. 63 respondents out of 110 (57.3%) agreed on selecting this factor as an EUF. In Table 7-9 and Appendix I Table-I1, the majority of the respondents concentrated on 3 and 4 scores. There is agreement to accept this EUF as an effective EUF as illustrated in the mean value result. NASA (2008) indicated this EUF. Although the result is not shown as the highest effective EUF, it is still considered as a possible EUF.

The distribution of effectiveness of the “specify simple shape of both building form and space of passive design “EUF is illustrated in Table 7-9. The effectiveness ranges from 1 very ineffective to 5 very effective. The mean value is 3.65 and has a standard deviation of .915, which shows that there is a good agreement about the effectiveness of the EUF among the designers. The histogram for this EUF is illustrated in Appendix I Table-I1. De Silva et al (2004) indicated the importance of simplified building element shapes for ease of maintenance. The designers have not paid attention to this EUF, even though it is essential.

Code	End User factors of passive Design Maintainability	Total Number	Frequency of scores					Mean	Std. Deviation	Ranking
			1	2	3	4	5			
FA1	Provide lighting and ventilation in expected maintenance areas	110	3	7	21	52	27	3.85	.960	12
FA2	Simplify interface of passive design elements and building façade	110	0	4	28	53	25	3.90	.789	6
FA3	Specify simple shape of both building form and space of passive design	110	1	8	42	37	22	3.65	.915	17
FA4	Utilize non-destructive disassembly passive design strategies	110	2	7	47	42	12	3.50	.843	18
FA5	Eliminate poor detailing of passive design space or element	110	0	7	22	49	32	3.96	.867	4
FA6	Design for ease to remove or replace lighting, ventilation and thermal comfort elements	110	1	3	30	53	23	3.85	.811	8
FA7	Design for ease to adjust lighting, ventilation and thermal comfort physical element features	110	1	3	20	51	35	4.05	.833	2
FA8	Design for ease of installing lighting, ventilation and thermal comfort element or material	110	1	6	29	46	28	3.85	.897	10
FA9	Provide passive design strategies that minimise the time for maintenance	110	3	7	22	43	35	3.91	1.010	5
FB1	Minimise use of unique materials of passive design strategies	110	6	10	46	33	15	3.37	1.012	19
FB2	Locate lighting, ventilation and thermal comfort materials for operability to minimise degradation	110	0	8	26	53	23	3.83	.844	13
FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity	110	0	4	14	57	35	4.12	.763	1
FC1	The cleanliness and maintenance of passive spaces enhances or interferes with well-being of occupants	110	3	3	26	54	24	3.85	.890	11
FC2	The interior of the passive building is designed to be easy to clean and maintain	110	1	4	17	57	31	4.03	.818	3
FC3	Access routes of passive space for transport of maintenance materials	110	1	6	38	44	21	3.71	.871	15
FC4	Critical lighting, ventilation and thermal comfort element should be visible for inspection	110	1	3	32	56	18	3.79	.779	14
FC5	All elements of the external passive building shell should be easy to access for maintenance and cleaning	110	0	5	23	65	17	3.85	.727	9
FC6	Optimise sizes for passive design openings for workmanship access	110	2	8	31	48	21	3.71	.922	16
FC7	Locate passive design elements where they are accessible for maintenance and repair	110	1	5	27	50	27	3.88	.865	7

Table 7-9: Descriptive Information of the First Part of the Questionnaire Survey: Passive Design Maintainability

7.5.2 Current Practice

The last part of the questionnaire asked the respondents about how often they considered EU needs during the design process in terms of the six main ATTs, as shown in Table 7-10:

Code	N	Percentage			Number of respondents			Mean	Std. Deviation
		Never	Sometimes	Always	Never	Sometimes	Always		
GA	110	9	28.2	70.9	1	31	78	2.70	.480
GB	110	3.6	30.9	65.5	4	34	72	2.62	.558
GC	110	3.6	30.9	65.5	4	34	72	2.62	.558
GD	110	6.4	44.5	49.1	7	49	54	2.43	.613
GG	110	7.3	36.4	56.4	8	40	62	2.49	.632
GF	110	9.1	43.6	47.3	10	48	52	2.38	.649

Table 7-10: Current practice of passive design attributes

7.5.2.1 Passive design Functionality

This attribute is one of the main ATTs of UCPBD, and the respondents’ result also reflects that. 78 (70.9%) respondents always keep the EU in their minds when they are specifying PDF. In contrast, 31 (28.2%) respondents sometimes keep the EU in their mind. The highest percentage in this ATT is for the architects who always keep the EU in their minds. Also, the percentage of this ATT is the highest percentage compared to the rest of the ATTs, as will be introduced in the following sections.

7.5.2.2 Passive design Performance and Usability

In this ATT, the majority of respondents also gave a high score for always keeping the EU in their mind when they design PDP. The total number is 72 (65.5%). The second rate was 34 (30.9%) respondents, who selected sometimes. The respondents gave the same score for the usability ATT.

7.5.2.3 Passive design Flexibility

54 (49.1%) of the respondents scored always for keeping the EU in their minds when designing PDFL. However, 49 (44.5%) of the respondents chose sometimes. In this ATT, the respondents who choose always and sometimes are close to each other. This shows the level of consideration of the EU during the design process. However, always considering the EU during the design process scored less than the previous ATTs, especially in terms of the always option.

7.5.2.4 Passive Design Reliability

For the reliability ATT, the architects preferred to give the highest score for always. Hence, 62 (56.4%) respondents indicated that they are always keeping the EU in their minds during PDR. However, the second highest response rate has been given for sometimes, where the total rate was 40 (36.4%) respondents out of 110.

7.5.2.5 Passive Design Maintainability

The maintainability ATT result is similar to the flexibility ATT. However, it was the least ATT that the designers selected for considering EU needs always. 52 (47.3%) of the architects selected that they are always keeping the EU in their mind during the design process. However, 48 (43.6%) of them preferred to say the level of considering user needs in PDM was sometimes.

7.5.3 Summary of this Chapter

The EUFs in this thesis have been introduced and described based on the findings of the survey. The findings have been analysed based on the 110 respondents, who are architects with different levels of experience and professional roles. The end user factors have been assessed based on the architects' perspectives. This chapter has highlighted the most effective EUFs that should be taken into account when developing the UCPBD model. In the following chapters, techniques such as data ranking and reduction will be used on the findings from this chapter, in order to develop the research model. These findings will be the foundation for this research. The essential part of this chapter has been gaining the data with the numbered responses. Without successful data collection, this research would not be successful.

Chapter Eight: Ranking the Findings

8.1 Introduction

UCPBD includes various EUFs, as introduced in the previous findings. The highest and lowest effective EUFs have been highlighted in the previous chapter. Ranking the EUFs means to have a list of them where they are ranked based on the level of their effectiveness. Also, the importance of ranking is usually when the researcher is including a huge list of EUFs, such as the number of EUFs in this research, which is 132. Ranking can support the researcher to save time when analysing the findings from this research. Also, the research can compare similar EUFs to decide which one will be selected to be involved in this research. The ranking will be based on the respondents' experience and professional role. These EUFs will be based on the following methods: mean value, standard deviation, coefficient of variance, and severity indices; and they will be ranked based on overall ranking, ATTs, and S-ATTs.

8.2 Methodology

The EUFs have been ranked based on the participants' experience and their professional role for both the first part and second part of the questionnaire. The ATTs mentioned above and the questionnaire in this study have been classified based on the literature review. 132 EUFs were extracted and classified to use in this questionnaire. The survey of UCPBD included six main ATTs. Each ATT has been divided into S-ATTs and each S-ATT includes EUFs. The hierarchy of this classification is shown in Figure 8:1.

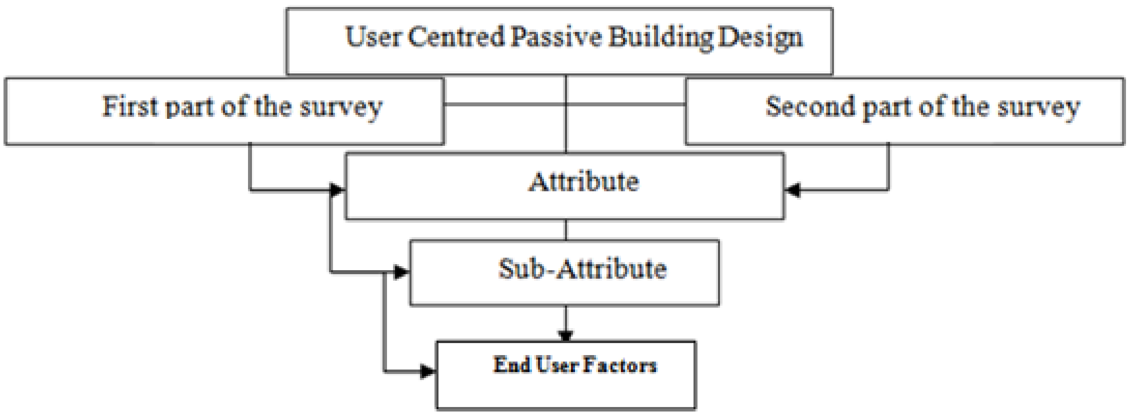


Figure 8:1: The Survey Hierarchy

The As and S-As are presented in Figure 8:2:

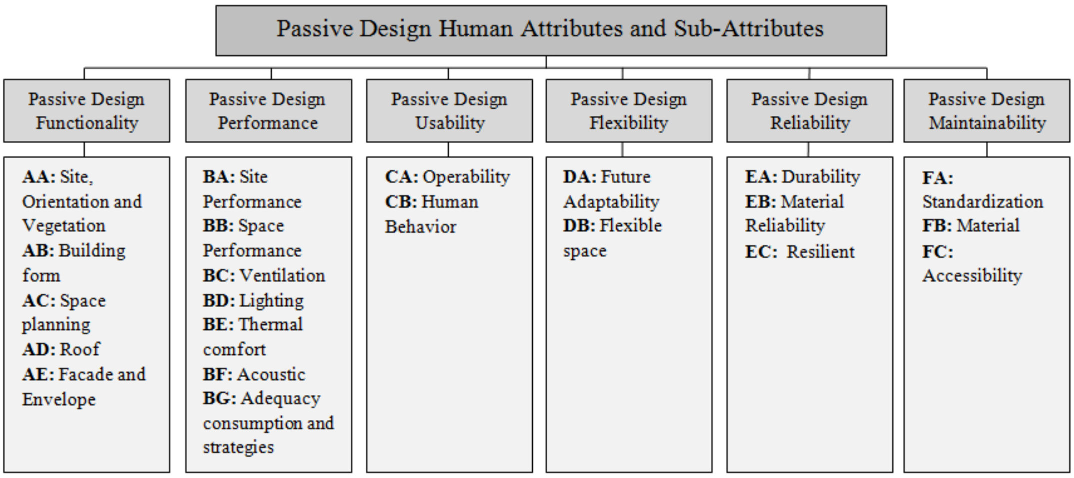


Figure 8:2: UCPBD Attributes and Sub-Attributes

Figure 8.3 illustrates the number of EUFs for each S-ATT. UCPBD consists of six main ATTs, 22 S-ATTs and 132 EUFs. PDF is a good example of an ATT and building form is a good example of an S-A. Figure 8-3 reflects the hierarchy of the questionnaire, which includes six main ATTs: functionality, performance, usability, flexibility, reliability and maintainability. PDF includes five S-ATTs with 43 EUFs. PDP includes 7 S-ATTs with a total of 27 EUFs. PDU includes two S-ATTs with a total number of 12 EUFs. PDFL is the fourth main ATT, which also includes two S-ATTs; the first S-ATT comprises 11 EUFs and the second S-ATT comprises 7 EUFs. The fifth ATT is PDR, which consists of durability, material reliability and resilience. Their EUFs are 7, 4 and 2 respectively. The last main ATT is PDM which includes three S-ATTs, which are standardisation, material and accessibility. The last S-ATT includes 7 EUFs. The material S-ATT comprises 3 EUFs. The standardisation S-ATT includes 9 EUFs.

Five scales - which are 1 (Very Ineffective), 2 (Ineffective), 3 (Neutral), 4 (Effective) and 5 (Very Effective) - have been used to assess each EUF. Each EUF reflects the level of effectiveness based on EU needs: 1 and 2 scores were for the not effective factor, 3 score was for the possible EUF and 4 and 5 scores were for the effective EUF.

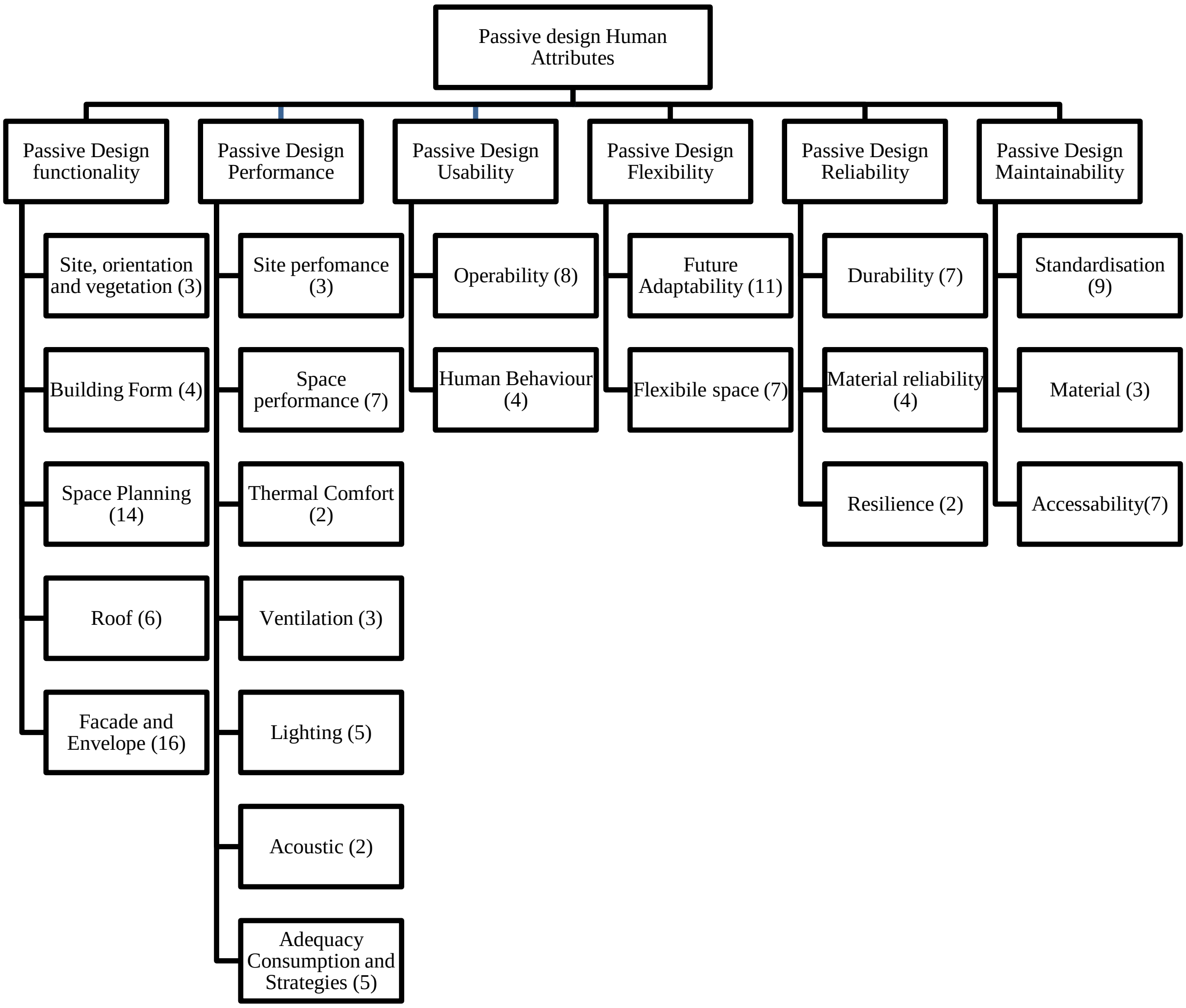


Figure 8:3: The number of EUFs of S-As of As of the questionnaire structure

8.3 Ranking and analysis of end user factors

There are various methods that can be used to analyse the findings of the questionnaire. Vakili-Ardebili (2004) referred to 4 methods to be used for ranking indicators, which are Mean weighted equation, Severity index, Coefficient of Variation and Kendall. The four methods have been used based on both SPSS. In terms of the calculation the researcher relied on Excel software too.

The suitable method to assess the effectiveness of the end user factor is mean weight equation, which is:

Mean weighted equation = $(\sum R*F)/n$.

Rating is from 1 to 5 and 3 is the neutral point.

The abbreviations are: R: 1-5 scores, F = frequency of responses and N = 110 respondents, which is the total number of respondents.

Severity index (S. I.) shows the rank of significance for each end user factor. The equation is as follows: S. I. = $[(\sum W*F) /n] * 100\%$.

The abbreviations are:

W= Weight for each rating (1, 2, 3, 4, 5), **F** = frequency of responses and **N** = 110 respondents, which is the total number of respondents.

In this research the equation will be:

S. I. = [(WR1*0.2+ WR2*0.4+ WR3*0.6+ WR4*0.8+ WR5*1) /110] * 100%.

The calculations of weighted mean and severity indices of indicators are presented in Tables 8-1 to 8-6.

Measuring the architects' harmonisation:

Coefficient of Variation (COV) is a measurement that can help when comparing variables from various respondents. Coefficient of Variation (COV) could be calculated by the following equation:

COV = (S / M) * 100%.

S= Standard deviation

M= Weighted mean. Also the calculation is presented in Tables 12-1 to 12-6.

Kendall could be calculated by the following equation:

W= 12*S / K2 *n* (n2-1)

Where:

S= sum of squares of deviations of EUFs

K= number of Respondents

n= number of EUFs in each Attribute

8.4 Ranking Data based on experience and professional role

The following sections will illustrate the statistical ranking of PDHAs. Tables 8-1 to 8-6 rank EUFs based on the results of both mean and standard deviation of EUFs. Also, in each table the ranking of S-ATT, ATT and overall ranking are presented. The ranking is based on severity indices. The results and discussion of the ranking are explained in the following sections.

8.4.1 Passive Design Functionality

This ATT consists of five S-ATTs namely (1) site, orientation and vegetation (2) space planning (3) building form (4) roof (5) façade and envelope. Each ATT includes several EUFs which are scored and ranked. The third of the EUFs for each ATT has been selected and highlighted then combined in Table 8-8, which shows the most effective EUFs. The total number of EUFs in this ATT is 43. 12 of these EUFs (almost one-third of the total) are highlighted in red in Table 8-1; these are the most effective EUFs.

The PDF attribute consists of five S-ATTs. The mean value of this group varies from 3.03 to 4.51. This is higher than 3 which is the neutral scale. In addition to that, the severity index ranges from 60.54% to 90.18%, which indicates level of effectiveness. The highest effective EUFs in Table 8-1 are AA2, AB3, AC3, AC4, AC9, AC10, AD1, AD2, AD3, AE9 and AE12.

The overall ranking of AA2 (Orient the building for optimum lighting, ventilation and thermal comfort) is 1 and its severity index is 90.18%, which is the highest EUF in this ATT as well as in the overall ranking. This result is expected because these EUFs can support the design to benefit from the natural environment in the optimum way. The passive space of the form can be designed based on this EUF. Several authors concentrated on this EUF. The United States Department of Energy (2000) referred to the importance of building location and orientation and how it can lead to maximising solar energy for the place. This reference is one of a number of authors who highlight this area. Table 8-1 shows that the mean values for all EUFs are more than neutral. This means all of them seem to be effective EUFs. The overall ranking of the AA2 (Orient the building for optimum lighting, ventilation and thermal comfort) is 1 out of 132 EUFs; its ranking in terms of ATT is also 1 out of 34 EUFs of PDF and 1 out of 3 in its S-ATTs, which are site, orientation and vegetation. This EUF (site, orientation and vegetation) is one of the S-ATTs of 5 S-ATTs of PDF. The severity index of this EUF is 90.18%, a coefficient of variation is 19.867, standard deviation is .896 and mean value = 4.51%. This EUF is the most effective EUF in overall ranking, PDF and site, orientation and vegetation S-ATTs.

The ranking based on participants' experience and professional role has been considered. The result fluctuated as it showed that there are some EUFs that differ from the other ranks' groups. For instance, in PDF AC2 (Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible) was ranked 16 by practising architects and the other ranking fluctuated between 23 and 35, as shown in Appendix J-Table JA. Another example, AE3 (Optimise south-facing glazing), was ranked as 33 by the architects who have between 5 and 10 years' experience; this means it is one of the lowest effective EUFs. This EUF was extracted based on Ahsan (2009). The effectiveness of a building being south facing should be taken into account whether in a hot or cold climate. In a hot climate, its location should be accurate, and it should provide the strategies that optimise lighting. In a cold climate, such as in the UK, the glassed area should be maximised to allow solar energy and natural ventilation to cross the space. The other EUFs fluctuate between 11 and 23, as shown in Table Appendix J-Table JA.

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	Overall Ranking			Kendall mean rank
						S	A	O	
AA1	110	3.82	.950	24.8691	76.36364	3	25	86	21.43
AA2	110	4.51	.896	19.867	90.18182	1	1	1	31.92
AA3	110	3.95	.956	24.2025	78.90909	2	14	46	23.35
AB1	110	3.77	.974	25.8355	75.45455	2	27	91	21.08
AB2	110	3.03	1.079	35.6106	60.54545	4	43	132	12.07
AB3	110	4.06	.921	22.6847	81.27273	1	9	32	25.11
AB4	110	3.75	.933	24.88	74.90909	3	30	98	20.37
AC1	110	3.64	.993	27.2802	72.72727	11	36	114	19.09
AC2	110	3.76	.867	23.0585	75.27273	8	28	94	20.30
AC3	110	4.15	.822	19.8072	82.90909	3	8	20	25.90
AC4	110	4.05	.866	21.3827	81.09091	4	10	33	24.80
AC5	110	3.65	.913	25.0137	73.09091	10	34	110	18.51
AC6	110	3.48	.965	27.7299	69.63636	13	41	127	17.01
AC7	110	3.72	.791	21.2634	74.36364	9	32	101	19.66
AC8	110	3.95	.887	22.4557	78.90909	5	13	45	22.64
AC9	110	4.18	.706	16.89	83.63636	2	6	17	26.29
AC10	110	4.25	.756	17.7882	84.90909	1	4	11	27.37

AC11	110	3.46	.964	27.8613	69.27273	14	42	128	16.47
AC12	110	3.80	.855	22.5	76	7	26	87	21.30
AC13	110	3.61	.939	26.0111	72.18182	12	38	119	18.63
AC14	110	3.83	.833	21.7493	76.54545	6	24	84	21.61
AD1	110	3.97	.710	17.8841	79.45455	3	12	42	23.18
AD2	110	4.18	.744	17.799	83.63636	1	7	18	26.33
AD3	110	4.00	.909	22.725	80	2	11	40	24.11
AD4	110	3.72	.890	23.9247	74.36364	6	31	99	19.88
AD5	110	3.94	.838	21.269	78.72727	4	15	51	22.98
AD6	110	3.90	.928	23.7949	78	5	18	59	22.67
AE1	110	3.58	.828	23.1285	71.63636	15	39	121	17.69
AE2	110	3.93	.798	20.3053	78.54545	5	17	55	22.90
AE3	110	3.93	.875	22.2646	78.54545	4	16	54	22.91
AE4	110	3.75	.950	25.3333	75.09091	11	29	96	20.69
AE5	110	3.83	.752	19.6345	76.54545	10	23	83	21.17
AE6	110	3.52	.946	26.875	70.36364	16	40	124	17.07
AE7	110	3.90	.789	20.2308	78	7	20	62	22.53
AE8	110	3.86	1.009	26.1399	77.27273	8	21	70	22.13
AE9	110	4.31	.875	20.3016	86.18182	1	2	7	28.40
AE10	110	3.69	.886	24.0108	73.81818	12	33	110	19.52
AE11	110	3.65	.903	24.7397	73.09091	13	35	111	19.27
AE12	110	4.26	.809	18.9906	85.27273	2	3	9	28.03
AE13	110	3.84	.873	22.7344	76.72727	9	22	81	21.59
AE14	110	3.90	.801	20.5385	78	6	19	61	22.63
AE15	110	3.64	.864	23.7363	72.72727	14	37	115	18.63
AE16	110	4.20	.833	19.8333	84	3	5	15	26.76

Table 8-1: User Centred Passive Building Design Attributes: Passive Design Functionality. S: Ranking based on Sub-Attribute, A: Ranking based on Attribute, O: Overall ranking and N.: Total Responses

8.4.2 Passive Design Performance

The PDP includes seven S-ATTs with 27 EUFs. The S-ATTs are site performance, space performance, thermal comfort, ventilation, lighting, acoustic and 'adequacy consumption and strategies'. Table 8-2 presents the statistical result of this ATT and ranking for each EUF and its S-ATTs. As Table 8-2 shows, the range of means is variable from 3.55 to 4.49. It is obvious that all means are more than 3, which means that all of them are more than neutral. This means that these could be considered as effective EUFs, on the one hand. On the other hand, their severity indexes are between 71.09091 and 89.81818. The highest ranks affiliate to BD1 (A comfortable internal air temperature) and BE2 (The adequacy of natural light in spaces) which present severity indices of 87.27273 and 89.81818 respectively. Their coefficient of variation is 19.867 and 18.0505 respectively. Their overall ranks are 2 and 3 out of 132 EUFs. Both of them are ranked 1 and 2 in terms of this ATT as well as 1 in terms of their S-ATTs. The highest rate of these EUFs reflects their effectiveness on UCPBD. The effectiveness of these EUFs has been confirmed by Fowler et al (2005) and Hassanain (2011) respectively. Both of them referred to the essentiality of considering the natural ventilation as well as natural lighting in the space. The designers' view matches the literature review. This reflects the essentiality of these EUFs in PBD.

In general, there is not a clear difference between the ranking of participants in terms of their professional role and experience. However; there are some simple differences, as shown in Table Appendix J-Table JB. For example, BD2 (The air quality in space enhances or interferes with well-being of occupants) has been ranked 11 by practising architects as one of the lowest effectiveness rates for this EUF. Fowler et al (2005) point out the importance of air quality to increase EU satisfaction. Two professional roles ranked this factor between 2 and 4. In terms of respondents' experience, this EUF is ranked between 4 and 5. Another example, BF1 (Select insulation against noises from corridors to give space privacy), is ranked 4 by respondents with 0-5 years' experience. However, the participants who have 5-10 years' experience and more than 10 years' experience ranked this EUF as 10 and 11 respectively. On the other hand, the ranking based on professional role was between 8 and 11, as shown in Table Appendix J-Table JB.

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	Overall Ranking			Kendall mean rank
						S	A	O	
BA1	110	4.34	.694	15.9908	86.72727	1	3	4	17.11
BA2	110	3.85	.837	21.7403	76.90909	2	21	79	12.00
BA3	110	3.75	.880	23.4667	75.09091	3	23	97	11.40
BB1	110	3.98	.857	21.5327	79.63636	1	14	41	13.58
BB2	110	3.93	.832	21.1705	78.54545	3	16	52	13.24
BB3	110	3.93	.821	20.8906	78.54545	4	17	53	13.20
BB4	110	3.76	.918	24.4149	75.27273	7	22	93	11.85
BB5	110	3.94	.941	23.8832	78.72727	2	15	50	13.40
BB6	110	3.86	.872	22.5907	77.27273	6	20	71	12.66
BB7	110	3.88	.810	20.8763	77.63636	5	19	66	12.50
BC1	110	4.11	.782	19.0268	82.18182	1	12	25	14.87
BC2	110	4.09	.808	19.7555	81.81818	2	13	27	14.50
BD1	110	4.49	.632	14.0757	89.81818	1	1	2	18.58
BD2	110	4.33	.679	15.6813	86.54545	2	4	5	16.95
BD3	110	4.31	.726	16.8445	86.18182	3	5	6	16.92
BE1	110	4.20	.739	17.5952	84	3	8	14	15.65
BE2	110	4.36	.787	18.0505	87.27273	1	2	3	17.40
BE3	110	4.26	.738	17.3239	85.27273	2	6	8	16.57
BE4	110	4.14	.840	20.2899	82.72727	4	11	22	15.26
BE5	110	3.72	.803	21.586	74.36364	5	24	102	10.90
BF1	110	4.15	.826	19.9036	83.09091	1	9	19	15.35
BF2	110	4.15	.811	19.5422	82.90909	2	10	21	15.27
BG1	110	3.57	.872	24.4258	71.45455	4	26	122	9.88
BG2	110	3.55	.808	22.7606	71.09091	5	27	123	9.53
BG3	110	3.65	.830	22.7397	72.90909	3	25	113	10.54
BG4	110	4.23	.820	19.3853	84.54545	1	7	12	16.02
BG5	110	3.90	.845	21.6667	78	2	18	63	12.84

Table 8-2: User Centred Passive Building Design Attributes: Passive Design Performance.
S: Ranking based on Sub-Attribute, A: Ranking based on Attribute, O: Overall ranking and N.: Total Responses

8.4.3 Passive Design Usability

This ATT consists of two main S-ATTs, operability and human behaviour, which include 12 EUFs. Operability includes 8 EUFs and human behaviour comprises 4 EUFs. Ranking in Table 8-3 shows that there are 7 EUFs out of 12 classified as the highest ranking for this ATT. The mean value of CA8 (Space to provide multi-user comfort (light, fresh air, optimal temperature) is 4.26. and its severity index is 85.27273. In addition to that, its coefficient of variation is 17.8873. These results show that it is the highest ranked in this attribute. Its rank in this S-ATT is 1 and the overall rank of EUF of UCPBD is 10. The majority of architects believe that a space should be comfortable for the EU in terms of lighting, natural ventilation and thermal comfort.

In this ATT, the rankings generally are quite close to each other and there is no clear difference between them. The CB1 (Reduce user stress and feelings of frustration due to lack of space) EUF is ranked 2 by practising architects, as shown in Appendix J-Table JC. The rest are fluctuating between 4 and 8. Hansen et al (2005) referred to the relationship between EU stress and the space area. This result reflects the level of awareness of the practising architects. This means that they address the issue of this EUF.

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	Overall Ranking			Kendall mean rank
						S	A	O	
CA1	110	3.76	.823	21.8883	75.27273	6	10	95	5.70
CA2	110	3.94	.793	20.1269	78.72727	5	8	49	6.38
CA3	110	3.66	.870	23.7705	73.27273	7	11	109	5.44
CA4	110	3.28	.879	26.7988	65.63636	8	12	131	4.04
CA5	110	4.08	.836	20.4902	81.63636	2	3	28	7.10
CA6	110	3.95	.817	20.6835	79.09091	4	7	44	6.52
CA7	110	4.06	.793	19.532	81.27273	3	5	31	7.00
CA8	110	4.26	.762	17.8873	85.27273	1	1	10	7.98
CB1	110	4.06	.911	22.4384	81.27273	2	4	30	7.06
CB2	110	4.22	.783	18.5545	84.36364	1	2	13	7.70
CB3	110	3.87	.900	23.2558	77.45455	4	9	67	6.25
CB4	110	4.04	.877	21.7079	80.72727	3	6	35	6.84

Table 8-3: User Centred Passive Building Design Attributes: Passive Design Usability.
S: Ranking based on Sub-Attribute, A: Ranking based on Attribute, O: Overall ranking and N.: Total Responses

8.4.4 Passive Design Flexibility

This ATT is the fourth ATT, which includes also two S-ATTs which are flexible space and future adaptability. Table 8-4 illustrates the ranking of both S-ATTs and with a total of 18 EUFs. The mean values of the EUFs vary from 3.45 and 4.07. This range also proves all EUFs are more than neutral =3. For this reason, all EUFs are highest effective EUFs. The severity index, which varies from 68.91 to 81.45, also confirms this. The highest rank for EUF is for DA9 (Design passive space to respond to changes in climate conditions); its severity index is 81.45 and its rank is 29 out of 132. Its coefficient of variation is 23.2187. Also, it is 1 out of 18 EUFs of this ATT and also 1 out of 11 EUFs of the flexible space S-ATT.

In Appendix J-Table JD there is a not big difference between various rankings. However, there are some EUFs which differ; for this reason they are highlighted in red. For instance, the DA2 (Design passive building to adapt for dysfunctional future utilisation) EUF is ranked 5 by the participants who have between 5-10 years' experience. The other rankings from participants based on their experience and professional role fluctuated between 9 and 17 as shown in Appendix J-Table JD. This could reflect the awareness of this EUF by architects who have 5-10 years' experience. This EUF can be enhancing design when to avoid any dysfunctional that could happen. Several authors, who referred to this EUF, for example, Fernandez (2003), mentioned that one of the designer's tasks is to consider future risk that could happen to the design functions. Another example, DB6 (Minimise partitions between passive spaces to control lighting, ventilation and thermal comfort) is ranked 5 by practising architects. However, those respondents who were academics and practising architects, as well as the academic architects, ranked this EUF 15 and 18 respectively. In terms of experience, 0-5 years, 5-10 years and more than 10 years ranked the EUF at 15, 13 and 14, as shown in Appendix J-Table JD.

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	Overall Ranking			Kendall mean rank
						S	A	O	
DA1	110	3.90	.957	24.5385	78	2	2	60	10.43
DA2	110	3.68	.938	25.4891	73.63636	10	13	108	9.02
DA3	110	3.69	1.047	28.374	73.81818	9	12	107	9.50
DA4	110	3.84	.894	23.2813	76.72727	6	7	80	9.79
DA5	110	3.86	.883	22.8756	77.27273	4	4	69	10.25
DA6	110	3.86	.872	22.5907	77.27273	5	5	72	10.28
DA7	110	3.87	.920	23.7726	77.45455	3	3	68	10.47
DA8	110	3.63	.907	24.9862	72.54545	11	15	117	8.66
DA9	110	4.07	.945	23.2187	81.45455	1	1	29	11.70
DA10	110	3.78	.952	25.1852	75.63636	8	9	90	9.88
DA11	110	3.82	.969	25.3665	76.36364	7	8	85	9.70
DB1	110	3.85	.900	23.3766	76.90909	1	6	78	10.11
DB2	110	3.45	1.019	29.5362	68.90909	7	18	129	7.71
DB3	110	3.63	.907	24.9862	72.54545	4	14	116	8.77
DB4	110	3.70	.904	24.4324	74	3	11	105	9.16
DB5	110	3.50	.926	26.4571	70	6	17	126	7.73
DB6	110	3.59	.941	26.2117	71.81818	5	16	120	8.54
DB7	110	3.72	.930	25.00	74.36364	2	10	100	9.30

Table8-4: User Centred Passive Building Design Attributes: Passive Design Flexibility.S: Ranking based on Sub-Attribute, A: Ranking based on Attribute, O: Overall ranking and N.: Total Responses

8.4.5 Passive Design Reliability

This ATT is the fifth ATT of UCPBD. It includes 3 S-ATTs and compromises 13 EUFs. The durability S-A includes 7 EUFs. Material reliability consists of 4 EUFs. The resilient S-ATT comprises 2 EUFs. The ranking result shows that there are six EUFs with highest ranking. The highest EUF of these six is EA6 (Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation). Its mean value is 4.20 and its severity index is 84%. This EUF is the highest effective EUF in this ATT and its S-ATT. Its coefficient of variation is 19.5714. Its overall ranking is 16 out of 132 EUFs, as shown in Table 8-5.

In reliability ranking, the EB2 (Use high quality material with long service life to handle passive functions) EU factor was ranked 9 by academic architects as a lowest effective EUF, even though ABCB (2006) focused on the fact that high quality material should last longer than material of a poorer quality. This result could be because these respondents are furthest from practising architecture; whereas, the professional role respondents ranked this EUF between 1 and 2. The classification based on the experience of the architects is ranked between 2 and 7. Also, EB3 (Consider the rate of expansion/contraction of material of passive design strategies) EUF is ranked 4 by the participants with more than 10 years' experience. This shows how experience can reflect on the architects' rankings. This could be based on feedback or the fact that they have had longer to increase their knowledge about the effectiveness of this EUF. ABCB (2006) confirmed the importance of considering the type of material when selecting it, in terms of its expansion and contraction. However, the participants with 0-5 years' and 5-10 years' experience have ranked this EUF as 9 and 13 respectively. In terms of professional role, two categories of respondent (practising architects and academic and practising architects) rank this EUF as 8; whereas the academic architects gave it a rank of 7. There is a clear fluctuation between 4 and 13 for the 6 classification groups, as shown in Appendix J-Table JE.

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	Overall Ranking			Kendall mean rank
						S	A	O	
EA1	110	3.92	.768	19.5918	78.36364	6	9	56	6.70
EA2	110	4.10	.741	18.0732	82	2	3	26	7.62
EA3	110	3.95	.788	19.9494	78.90909	5	7	47	6.91
EA4	110	4.02	.801	19.9254	80.36364	4	6	39	7.27
EA5	110	4.03	.851	21.1166	80.54545	3	4	36	7.42
EA6	110	4.20	.822	19.5714	84	1	1	16	8.15
EA7	110	3.89	.850	21.8509	77.81818	7	10	64	6.68
EB1	110	4.02	.919	22.8607	80.36364	2	5	38	7.29
EB2	110	4.11	.902	21.9465	82.18182	1	2	24	7.75
EB3	110	3.95	.855	21.6456	78.90909	3	8	48	7.00
EB4	110	3.62	1.075	29.6961	72.36364	4	13	118	5.72
EC1	110	3.79	.899	23.7203	75.81818	1	11	89	6.28
EC2	110	3.77	.885	23.4748	75.45455	2	12	92	6.21

Table 8-5: User Centred Passive Building Design Attributes: Passive Design Reliability.S: Ranking based on Sub-Attribute, A: Ranking based on Attribute, O: Overall ranking and N.: Total Responses

8.4.6 Passive Design Maintainability

This ATT includes three S-ATTs namely: standardisation, material and accessibility. The total number is 19 EUFs. 4 EUFs out of the 19 are highlighted as some of the highest EUFs, as shown in Table 8-6; they are: FA5 (Eliminate poor detailing of passive design space or element), FA7 (Design for ease to adjust lighting, ventilation and thermal comfort physical element features), FB3 (Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity) and FC2 (The interior of the passive building is designed to be easy to clean and maintain).The means for these EUFs range from 3.96 to 4.12. In terms of the severity index, they range from 79.27 % and 82.36%. In addition to that, their coefficients of variation are between 18.5194 and 21.8939. FB3 (Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity) has the highest effective EUF in ATTs in terms of its mean value and severity index.

FA1 (Provide lighting and ventilation in expected maintenance areas) is ranked 1 by the participants with between 5 and 10 years' experience. The other 5 groups fluctuated between 6 and 15. In addition to that, FA7 (Design for ease to adjust lighting, ventilation and thermal comfort physical element features) is ranked 13 by the participants who have between 5 to 10 years' experience. The Northumberland National Park Authority (2006) indicated the importance of adjustment of material and elements to reduce the maintenance problem. However, the architects with 0-5 years' experience and those with more than 10 years' experience ranked it 5 and 1 respectively. Another EUF, FC2 (The interior of the passive building is designed to be easy to clean and maintain), was ranked 10 by the architects with 5-10 years' experience. As shown in Appendix J-Table JF, the other EUFs were ranked close to each other; there are no clear differences between them.

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	Overall Ranking			Kendall mean rank
						S	A	O	
FA1	110	3.85	.960	24.9351	76.90909	7	12	77	10.17
FA2	110	3.90	.789	20.2308	78	4	6	58	10.45
FA3	110	3.65	.915	25.0685	72.90909	8	17	112	8.96
FA4	110	3.50	.843	24.0857	70	9	18	125	7.99
FA5	110	3.96	.867	21.8939	79.27273	2	4	43	11.05

FA6	110	3.85	.811	21.0649	77.09091	5	8	73	10.05
FA7	110	4.05	.833	20.5679	81.09091	1	2	34	11.48
FA8	110	3.85	.897	23.2987	77.09091	6	10	75	10.16
FA9	110	3.91	1.010	25.8312	78.18182	3	5	57	10.71
FB1	110	3.37	1.012	30.0297	67.45455	3	19	130	7.26
FB2	110	3.83	.844	22.0366	76.54545	2	13	82	10.05
FB3	110	4.12	.763	18.5194	82.36364	1	1	23	12.12
FC1	110	3.85	.890	23.1169	76.90909	4	11	76	9.94
FC2	110	4.03	.818	20.2978	80.54545	1	3	37	11.31
FC3	110	3.71	.871	23.4771	74.18182	6	15	103	9.06
FC4	110	3.79	.779	20.5541	75.81818	5	14	88	9.75
FC5	110	3.85	.727	18.8831	77.09091	3	9	74	10.00
FC6	110	3.71	.922	24.8518	74.18182	7	16	104	9.16
FC7	110	3.88	.865	22.2938	77.63636	2	7	65	10.32

Table 8-6: User Centred Passive Building Design Attributes: Passive Design Maintainability. S: Ranking based on Sub-Attribute, A: Ranking based on Attribute, O: Overall ranking and N.: Total Responses

8.4.7 Current practice

This section looks at the architects' perspectives about the level of integration of EUFs into PBD during design process. As illustrated in Table 8-7, the architects believe that PDF is the most considered ATT by architects. The second ATT is performance, for which the designers keep the EU in their mind when they design PBD. The third ATT is PDU which has the same result based on the mean value. The fourth ATT is reliability, based on its mean value. The fifth ATT is flexibility. Finally, the lowest ATT for which the designers keep the EU in their mind when they design PBD is maintainability. However, the rankings are different based on the professional role and designer experience, except for the practising architects between 5-10 years.

Q	N	Mean	Std. Deviation	Coefficient of Variation	L1 T.R:29	L2 T.R:49	L3 T.R:32	M1 T.R:33	M2 T.R:23	M3 T.R:54	O
GA	110	2.70	48.0	17.7778	1	2	1	1	1	2	1
GB	110	2.62	55.8	21.2977	2	3	2	4	2	1	2
GC	110	2.62	55.8	21.2977	3	1	3	2	4	3	3
GD	110	2.43	61.3	25.2263	5	4	6	6	6	4	5
GE	110	2.49	63.2	25.3815	4	5	4	3	5	5	4
GF	110	2.38	64.9	27.2689	6	6	5	5	3	6	6

Table 8-7: Current practice. The abbreviationS: L1= Architect practising, L2: Academic and Architect practising, L3: Academic Architect, M1: 0-5 years experience, M2: 5-10 years experience, M3: More than 10 years Experience, S: Ranking based on Sub-Attribute, A: Ranking based on Attribute, O: Overall ranking and N.: Total Responses

8.5 Conclusion of overall ranking

In the Table 8-8, the most effective EUFs have been extracted and listed based on their highest overall ranking. Tables 8-8 include 44 EUFs as the highest effective EUFs based on their ranking in UCPBD. These 44 are one-third of the 132 EUFs, and are the highest effective EUFs. Severity index has been used as a mean for ranking, plus mean value and standard deviation, to be more reliable. The mean value of all EUFs is more than 3, which is the neutral score. This means all EUFs can be selected as effective EUFs of UCPBD. This result was based on the perspectives of 110 architects with different professional roles and different experience.

Q	Description	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	Overall Ranking		
							S	A	O
AA2	Orient the building for optimum lighting, ventilation and thermal comfort	110	4.51	.896	19.867	90.18182	1	1	1

AB3	Shape the building to maximise exposure to [winter sun and summer breezes]	110	4.06	.921	22.6847	81.27273	1	9	32
AC3	Use central atriums, courtyards and lobbies (elevators, and stairs can be locate in central areas) for optimum ventilation	110	4.15	.822	19.8072	82.90909	3	8	20
AC4	Provide vertical air shafts/stacks, and central exhaust paths to promote interior airflow	110	4.05	.866	21.3827	81.09091	4	10	33
AC9	Design plan to create buffer zones from the summer radiation	110	4.18	.706	16.89	83.63636	2	6	17
AC10	Plan specific spaces or functions to coincide with solar orientation	110	4.25	.756	17.7882	84.90909	1	4	11
AD1	Use roof elements for stack effect ventilation	110	3.97	.710	17.8841	79.45455	3	12	42
AD2	Use skylight, light tube and clerestory for natural illumination	110	4.18	.744	17.799	83.63636	1	7	18
AD3	Use solar roof collectors on the south-oriented surfaces	110	4.00	.909	22.725	80	2	11	40
AE9	Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort	110	4.31	.875	20.3016	86.18182	1	2	7
AE12	Orient openings to facilitate natural ventilation	110	4.26	.809	18.9906	85.27273	2	3	9
AE16	Provide high levels of insulation in the façade and building envelope to reduce summer conductive gain and to preserve internal heat	110	4.20	.833	19.8333	84	3	5	15
BA1	Utilizing views and orientation	110	4.34	.694	15.9908	86.72727	1	3	4
BB1	Durable, high quality finishes	110	3.98	.857	21.5327	79.63636	1	14	41
BC1	The temperature controls provide for the needs of different occupants	110	4.11	.782	19.0268	82.18182	1	12	25
BC2	Thermal comfort in spaces enhances or interferes with well-being of occupants	110	4.09	.808	19.7555	81.81818	2	13	27
BD1	A comfortable internal air temperature	110	4.49	.632	14.0757	89.81818	1	1	2
BD2	The air quality in space enhances or interferes with well-being of occupants	110	4.33	.679	15.6813	86.54545	2	4	5
BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)	110	4.31	.726	16.8445	86.18182	3	5	6
BE1	The adequacy of light sufficiency in spaces	110	4.20	.739	17.5952	84	3	8	14
BE2	The adequacy of natural light in spaces	110	4.36	.787	18.0505	87.27273	1	2	3
BE3	The visual comfort of the lighting (e.g., glare, reflections, contrast)	110	4.26	.738	17.3239	85.27273	2	6	8
BE4	The lighting quality enhances or interferes with well-being of occupants	110	4.14	.840	20.2899	82.72727	4	11	22
BF1	Select insulation against noises from corridors to give space privacy	110	4.15	.826	19.9036	83.09091	1	9	19
BF2	Utilize good acoustic conditions	110	4.15	.811	19.5422	82.90909	2	10	21
BG4	Reduce consumption of water, energy and electricity	110	4.23	.820	19.3853	84.54545	1	7	12
CA5	Incorporate passive design technologies which are easy to operate by multiple users	110	4.08	.836	20.4902	81.63636	2	3	28
CA6	Accessible passive design controls for multiple users	110	3.95	.817	20.6835	79.09091	4	7	44
CA7	Design passive space that is well-suited for multi-user activities and capabilities	110	4.06	.793	19.532	81.27273	3	5	31
CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)	110	4.26	.762	17.8873	85.27273	1	1	10
CB1	Reduce user stress and feelings of frustration due to lack of space	110	4.06	.911	22.4384	81.27273	2	4	30
CB2	Consider safety, health and physical well-being needs for multiple users of passive buildings	110	4.22	.783	18.5545	84.36364	1	2	13
CB4	Consider users' cultural image, identity, lifestyle, psychological needs and perceptions in line with passive lighting, ventilation and thermal comfort strategies	110	4.04	.877	21.7079	80.72727	3	6	35
DA9	Design passive space to respond to changes in climate conditions	110	4.07	.945	23.2187	81.45455	1	1	29
EA2	Provide optimum drainage and venting to minimise accumulation of moisture	110	4.10	.741	18.0732	82	2	3	26

EA4	Select components that are resistant to environmental agents	110	4.02	.801	19.9254	80.36364	4	6	39
EA5	Compatibility in joining lighting, ventilation and thermal comfort elements together	110	4.03	.851	21.1166	80.54545	3	4	36
EA6	Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation	110	4.20	.822	19.5714	84	1	1	16
EB1	Consider passive building joint seals to resist infiltration of moisture or deleterious materials	110	4.02	.919	22.8607	80.36364	2	5	38
EB2	Use high quality material with long service life to handle passive functions	110	4.11	.902	21.9465	82.18182	1	2	24
FA5	Eliminate poor detailing of passive design space or element	110	3.96	.867	21.8939	79.27273	2	4	43
FA7	Design for ease to adjust lighting, ventilation and thermal comfort physical element features	110	4.05	.833	20.5679	81.09091	1	2	34
FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity	110	4.12	.763	18.5194	82.36364	1	1	23
FC2	The interior of the passive building is designed to be easy to clean and maintain	110	4.03	.818	20.2978	80.54545	1	3	37

Table 8-8:Most Effective Ranked End User Factors Extracted for User Centred Passive Building Design

8.6 Average Severity Indices of user centred passive building design attributes

The ranking in this research has been assessed based on the severity index in terms of ATT and S-ATTs of UCPBD. In Figure 8:4, the numbers from 1 to 6 reflect the ATTs of the design (1= Passive design functionality, 2= Passive Design Performance, 3=Passive Design Usability, 4=Passive design Flexibility, 5=Passive Design Reliability and 6=Passive Design Maintainability). The highest severity indices percentage belongs to PDP with 80.32%. The lowest severity belongs to PDFL with 74.39%. The other As vary between 76.49% and 79%. Generally, in UCPBD all ATTs are deemed effective and significant. PDFL is the lowest ranking. This could be because of the lack of considering this ATT or understanding that its EUFs can lead to improving the design in current and future practice.

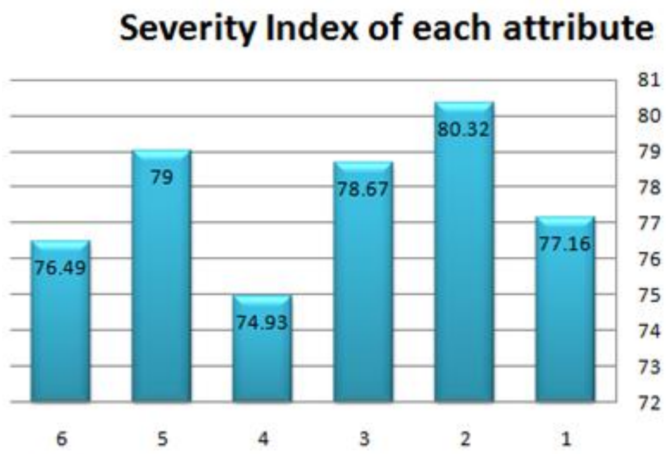


Figure 8:4: Average severity index of each attribute: 1= Passive design functionality, 2= Passive Design Performance, 3=Passive Design Usability, 4=Passive design Flexibility, 5=Passive Design Reliability and 6=Passive Design Maintainability

8.7 Average Severity Indices of user centred passive building design sub- attributes

The ranking in this research has been assessed based on the severity index in terms of S-ATTs of UCPBD. Also, in Figure 8:5, the percentages of 22 S-ATTs of all ATTs are shown. The highest severity indices percentage belongs to PDP ATT and to lighting performance S-ATTs which equal 78.5. However, the lowest severity belongs to PDFL for flexible space S-ATT at 72.6%. The other ATTs fluctuate between 73.1% and 83%. Generally, in UCPBD all S-ATTs are effective and significant. The lowest severity in PDFL could be due to the lack of considering this ATT or understanding that its EUFs can lead to improving the design in current and future practice.

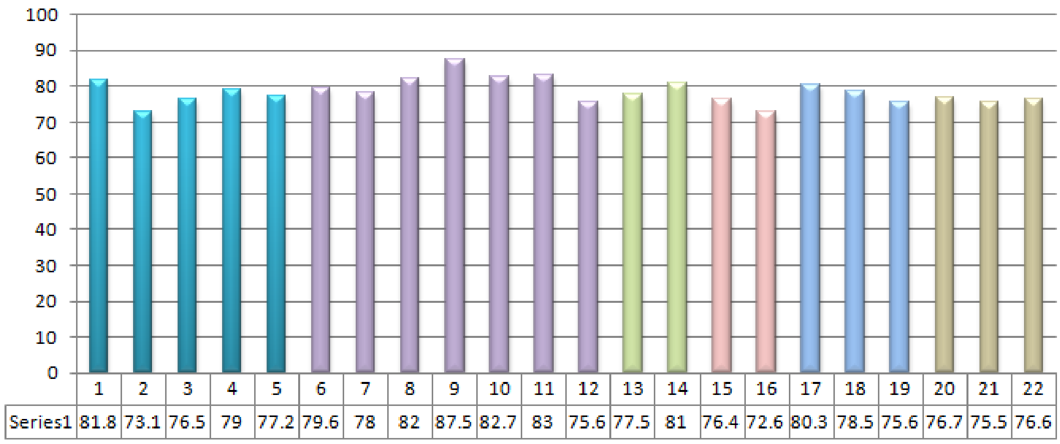


Figure 8:5: Average severity index of each sub-attribute: Passive Design Functionality: 1= site, orientation and vegetation, 2 building form, 3= space planning, 4=roof, 5= façade and envelope. Passive Design Performance: 6= site performance, 7=space performance, 8= natural ventilation, 9= lighting, 10= thermal comfort, 11= acoustic, 12= adequacy consumption and strategies. Passive Design Usability: 13=operability, 14=human behaviour. Passive design Flexibility: 15= future adaptability, 16= flexible space. Passive Design Reliability: 17=durability, 18: material reliability, 19=resilience. Passive Design Maintainability: 20=standardisation, 21=material, 22= accessibility

8.8 Summary of this Chapter

This chapter has used mean value, severity index and standard deviation to assess the effectiveness of each EUF as well as the PDHAs to determine the effectiveness of EUFs in each ATT. The result of the ranking has been illustrated from Table 8-1 to Table 8-8. Table 8-8 was the result of the ranking which includes 44 EUFs. All EUFs can be classified to be EUFs of the UCPBD model because the mean values of all of them are more than the neutral score. The 44 extracted EUFs will be used in the next two chapters. In Chapter 9, there will be an ANOVA analysis in order to compare the architects' views based on both their professional role and their experience, as well as the reliability analysis. Then Chapter 10 will include data analysis and reduction of data to determine some clusters for developing the new conceptual model.

Chapter Nine: Hypothesis and Reliability Testing

9.1 Introduction:

The previous chapters described the results of the survey as well as the ranking of the results. There are differences between rankings based on professional role and EU experience. For this reason, this chapter will test the hypothesis of PDHAs based on both respondents' experience and professional role through using ANOVA method. The analysis will be for all the EUFs. This will be shown and discussed in the following sections.

9.2 Method

Two methodologies were used to compare the responses of participants based on their professional role as well as on their experience: (ANOVA) one way analysis is used to compare the means of respondents. This will also help to identify the significant differences between the respondents. Interpreting the result will lead to find out FS values and Chi-square, degree of freedom and Kendall method. This will help the researcher to understand if there are differences between the respondents' perceptions (P values<0.05). Dallal GE (2007) defined the P.Value as *"The standard level of significance used to justify a claim of a statistically significant effect is 0.05. For better or worse, the term statistically significant has become synonymous with P $\leq$0.05."*. In SPSS the Anova, FS values means *"The F test employs the statistic (F) to test various statistical hypotheses about the mean (or means) of the distributions from which a sample or a set of samples have been drawn. It is noteworthy that as demonstrated in this tutorial, the t test is a special form of the F test."* (The Animated Software Company,2013). , Chi-square, degree of freedom (df) and Kendall are provided to calculate it directly, as shown in the following sections.

9.3 Analysis of participants' responses based on their professional role

The professional role of participants has been divided into three main categories, as shown in Table 9-1. The first category is the practising architects, the second category is respondents who are both academics and practising architects, and the last category is academic architects. Based on the analysis, the total number of respondents for each category is illustrated in the following table.

1-Practising Architects		2-Academic and Practising Architects		3-Academic Architect		Total	
No	Percentage	No	Percentage	No	Percentage	No	Percentage
29	26.4%	49	44.5%	32	29.1%	110	100%

Table 9-1: Respondents' classification based on their professional role

In the above table, the highest percentage is for respondents who are both academics and practising architects, which is equal to 44.5% with a total of 49. For this reason, their results will be compared based on the average rating, then they will be ranked and the hypotheses will be tested through the ranking.

9.3.1 ANOVAs Rating Based on Architects' Professional role

9.3.1.1 Passive design Functionality

The statistics are reported in Tables 9-3 and 9-4. The result of ranking of each group shows that there is little difference or no significance between groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_0 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design functionality sub attributes: site, orientation and vegetation, building form, space planning, roof and façade" based on their professional role.

A_{01} ($p > 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design functionality sub attributes: site, orientation and vegetation, building form, space planning, roof and façade" based on their professional role.

The results of ANOVA analysis of each EUF of PDF are shown in Tables 9-3 and 9-4. The ANOVA explains whether the overall FS values for EUFs were significant. However, statistically there is no significant difference between architects' responses for each EUF. In order, all of them are >.05. This confirms the null hypothesis.

ANOVA analysis shows that the top 10 EUFs ranked are AB2, AC6, AC8, AC9, AC12, AD2, AD5, AD6, AE11, and AE16. All of them have no statistically significant differences. These EUFs have been selected based on the critical literature review, as shown in Table 9-2.

Code	End user factors	Reference
AB2	Use low mass construction to allow rapid heat-up or cooling of structure	The Concrete Centre (2010)
AC6	The proportion of the plan is long and narrow (use linear plan form, or a similar strategy) to optimise day lighting	BIM (2011) and Ministry for the Environment (2008)
AC8	Consider interior surface colours and finishes for optimum day lighting	Li and Tsang (2008)
AC9	Design plan to create buffer zones from the summer radiation	Ip and Miller (2006)
AC12	Provide solar-oriented interior zone to store and maximise solar heat gain	Ministry for the Environment (2008) and Department of Education, Northern Ireland (DENI) and Corp Creator (1998)
AD2	Use skylight, light tube and clerestory for natural illumination	BIM (2011)
AD5	Use ventilated roof to lower summer gains through roof	Gut and Ackerknecht (1993)
AD6	Use of an appropriate shape and angle of the roof for optimum ventilation and thermal comfort	United States Department of Energy (2000) and Ahsan (2009)
AE11	Use exterior elements to direct summer wind flow into the interior	BIM (2011)
AE16	Provide high levels of insulation in the façade and building envelope to reduce summer conductive gain and to preserve internal heat	Ahsan (2009).

Table 9-2: The top end user factors of passive design functionality based on the F-value.

		Sum of Squares	df	Mean Square	F	P Value
AA1	Between Groups	.744	2	.372	.408	.666
	Within Groups	97.620	107	.912		
	Total	98.364	109			

AA2	Between Groups Within Groups Total	.827 86.664 87.491	2 107 109	.413 .810	.510	.602
AA3	Between Groups Within Groups Total	.966 98.707 99.673	2 107 109	.483 .922	.523	.594
AB1	Between Groups Within Groups Total	1.032 102.286 103.318	2 107 109	.516 .956	.540	.584
AB2	Between Groups Within Groups Total	3.651 123.268 126.918	2 107 109	1.825 1.152	1.584	.210
AB3	Between Groups Within Groups Total	1.296 91.259 92.555	2 107 109	.648 .853	.760	.470
AB4	Between Groups Within Groups Total	1.361 93.512 94.873	2 107 109	.680 .874	.779	.462
AC1	Between Groups Within Groups Total	.191 107.263 107.455	2 107 109	.096 1.002	.095	.909
AC2	Between Groups Within Groups Total	.947 80.907 81.855	2 107 109	.474 .756	.626	.537
AC3	Between Groups Within Groups Total	.545 73.127 73.673	2 107 109	.273 .683	.399	.672
AC4	Between Groups Within Groups Total	1.459 80.214 81.673	2 107 109	.730 .750	.973	.381
AC5	Between Groups Within Groups Total	1.295 89.578 90.873	2 107 109	.647 .837	.773	.464
AC6	Between Groups Within Groups Total	3.818 97.646 101.464	2 107 109	1.909 .913	2.092	.128
AC7	Between Groups Within Groups Total	.222 68.042 68.264	2 107 109	.111 .636	.174	.840
AC8	Between Groups Within Groups Total	3.427 82.245 85.673	2 107 109	1.714 .769	2.229	.113
AC9	Between Groups Within Groups Total	1.333 53.030 54.364	2 107 109	.667 .496	1.345	.265
AC10	Between Groups Within Groups Total	.228 62.145 62.373	2 107 109	.114 .581	.196	.822
AC11	Between Groups Within Groups Total	.690 100.664 101.355	2 107 109	.345 .941	.367	.694
AC12	Between Groups Within Groups Total	4.125 75.475 79.600	2 107 109	2.062 .705	2.924	.058
AC13	Between Groups Within Groups Total	.687 95.504 96.191	2 107 109	.343 .893	.385	.682
AC14	Between Groups Within Groups Total	.047 75.671 75.718	2 107 109	.023 .707	.033	.967

Table 9-3: The PDF: F-value and significant value of the ANOVA analysis

		Sum of Squares	df	Mean Square	F	P-Value
AD1	Between Groups	.693	2	.347	.684	.507
	Within Groups	54.225	107	.507		
	Total	54.918	109			
AD2	Between Groups	2.302	2	1.151	2.121	.125
	Within Groups	58.061	107	.543		
	Total	60.364	109			
AD3	Between Groups	.397	2	.199	.237	.789
	Within Groups	89.603	107	.837		
	Total	90.000	109			
AD4	Between Groups	1.155	2	.577	.726	.486
	Within Groups	85.109	107	.795		
	Total	86.264	109			
AD5	Between Groups	3.148	2	1.574	2.294	.106
	Within Groups	73.406	107	.686		
	Total	76.555	109			
AD6	Between Groups	2.123	2	1.061	1.237	.294
	Within Groups	91.777	107	.858		
	Total	93.900	109			
AE1	Between Groups	.107	2	.053	.076	.926
	Within Groups	74.657	107	.698		
	Total	74.764	109			
AE2	Between Groups	.296	2	.148	.229	.795
	Within Groups	69.122	107	.646		
	Total	69.418	109			
AE3	Between Groups	.470	2	.235	.303	.739
	Within Groups	82.948	107	.775		
	Total	83.418	109			
AE4	Between Groups	.154	2	.077	.084	.920
	Within Groups	98.219	107	.918		
	Total	98.373	109			
AE5	Between Groups	.536	2	.268	.469	.627
	Within Groups	61.182	107	.572		
	Total	61.718	109			
AE6	Between Groups	.954	2	.477	.529	.591
	Within Groups	96.509	107	.902		
	Total	97.464	109			
AE7	Between Groups	.499	2	.250	.396	.674
	Within Groups	67.401	107	.630		
	Total	67.900	109			
AE8	Between Groups	1.719	2	.860	.842	.434
	Within Groups	109.235	107	1.021		
	Total	110.955	109			
AE9	Between Groups	.127	2	.064	.082	.922
	Within Groups	83.364	107	.779		
	Total	83.491	109			
AE10	Between Groups	.520	2	.260	.328	.721
	Within Groups	84.971	107	.794		
	Total	85.491	109			
AE11	Between Groups	3.131	2	1.566	1.954	.147
	Within Groups	85.741	107	.801		
	Total	88.873	109			
AE12	Between Groups	.273	2	.136	.205	.815
	Within Groups	71.082	107	.664		
	Total	71.355	109			
AE13	Between Groups	.156	2	.078	.100	.905
	Within Groups	82.899	107	.775		
	Total	83.055	109			
AE14	Between Groups	1.090	2	.545	.847	.431
	Within Groups	68.810	107	.643		
	Total	69.900	109			
AE15	Between Groups	.658	2	.329	.436	.648
	Within Groups	80.796	107	.755		
	Total	81.455	109			
AE16	Between Groups	3.448	2	1.724	2.557	.082
	Within Groups	72.152	107	.674		
	Total	75.600	109			

Table 9-4: The PDF: F-value and significant value of the ANOVA analysis

9.3.1.2 Passive design Performance

ANOVA also has been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason, the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_2 ($p > 0.05$): There is no statistically significant difference between the architects architects' perceptions regarding the level of effectiveness of EUFs of "passive design performance sub-attributes: site performance, space performance, thermal comfort performance, natural ventilation performance, day lighting performance, acoustic performance and adequacy and consumption strategies design factors" based on their professional role.

A_{02} ($p > 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design performance sub-attributes: site performance, space performance, thermal comfort performance, natural ventilation performance, day lighting performance, acoustic performance and adequacy and consumption strategies design factors" based on their professional role.

Each EUF has been analysed by using ANOVA. The results of this analysis are shown in Tables 9-5 and 9-6. FS values for EUF were significant. Based on analysis of the three types of professional roles, only 2 EUFs out of the 27 EUFs had responses that differed significantly. These two EUFs were BB1 and BG2. This is highlighted in Tables 9-5 and 9-6. This explains that one of the professional roles rates that the EUFs differ significantly more than other professional roles. In this case, the null hypothesis is rejected.

ANOVA shows us that there is some significant difference. However, which specific means are different from other is not provided in the ANOVA analysis. For this reason, Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was chosen. However, only the BB1 and BG2 were significantly different, as shown in Figure 9-7. The significant value is less than .05 and there is a difference between the participants' responses.

The highest ratings of the 10 EUFs are BA1, BB1, BB2, BB3, BD3, BE1, BE4, BG2, BG3, and BG4. The previous EUFs were expected to be in the top rank because all of them had been selected based on the literature review. The F-values of the two EUFs (BB1 and BG2) are $F (7.833) =4.616$, $p=.012$ and $F (7.833) =3.127$, $p=.044$ respectively. The Post Hoc Tukey test was used to determine which professional role is different from the others. This shows there is a difference between the agreements between these EUFs. BB1 (Durable, high quality finishes) and BG2 (Utility passive design cores uniformly designed and vertically stacked) as EUFs were selected based on the critical literature review. Li and Tsang (2008) referred to how the finishes and colours can reflect on the performance of PL. The different views between the different professional roles could because of their interest or knowledge. For example, this could be more important for the architects who are practising because their interactions with design are more than those of the academic architects. Also, dealing with customers at some stage could make a clear difference between them, as illustrated in Table 9-9.

In this research Kendall's nonparametric test has also been used, as shown in Table 9-8. This is to measure the ranks between EUFs for each ATT through investigation of the agreement or concordance between the participants' responses on the effectiveness of EUFs in PBD. Kendall's test can help to measure the agreement between the categories of professional role as well as between the rankings of EUFs. 0 means no agreement and 1 perfect agreement and concordance. The values of Kendall's are between.108 and .150 for the three professional role categories, as illustrated in Table 9-8. The lowest value of Kendall's coefficient refers to the weak agreement between the respondents. However, there is still agreement between them. Also, the value of significant level of all is P=0.000. This means the null hypothesis has to be rejected, and the alternative hypothesis should be accepted, which is that there is agreement between the professional roles.

ANOVA

		Sum of Squares	df	Mean Square	F	P Value
BA1	Between Groups	1.283	2	.641	1.338	.267
	Within Groups	51.272	107	.479		
	Total	52.555	109			
BA2	Between Groups	.519	2	.259	.366	.694
	Within Groups	75.854	107	.709		
	Total	76.373	109			
BA3	Between Groups	.620	2	.310	.396	.674
	Within Groups	83.753	107	.783		
	Total	84.373	109			
BB1	Between Groups	6.351	2	3.175	4.616	.012
	Within Groups	73.613	107	.688		
	Total	79.964	109			
BB2	Between Groups	2.471	2	1.235	1.812	.168
	Within Groups	72.948	107	.682		
	Total	75.418	109			
BB3	Between Groups	1.525	2	.762	1.135	.325
	Within Groups	71.893	107	.672		
	Total	73.418	109			
BB4	Between Groups	.885	2	.442	.520	.596
	Within Groups	90.970	107	.850		
	Total	91.855	109			
BB5	Between Groups	1.606	2	.803	.905	.408
	Within Groups	94.948	107	.887		
	Total	96.555	109			
BB6	Between Groups	.520	2	.260	.338	.714
	Within Groups	82.434	107	.770		
	Total	82.955	109			
BB7	Between Groups	.380	2	.190	.286	.752
	Within Groups	71.084	107	.664		
	Total	71.464	109			
BC1	Between Groups	.397	2	.199	.321	.726
	Within Groups	66.294	107	.620		
	Total	66.691	109			
BC2	Between Groups	.435	2	.218	.330	.720
	Within Groups	70.655	107	.660		
	Total	71.091	109			
BD1	Between Groups	.252	2	.126	.312	.733
	Within Groups	43.239	107	.404		
	Total	43.491	109			
BD2	Between Groups	.550	2	.275	.593	.555
	Within Groups	49.668	107	.464		
	Total	50.218	109			
BD3	Between Groups	1.141	2	.570	1.083	.342
	Within Groups	56.350	107	.527		
	Total	57.491	109			
BE1	Between Groups	2.553	2	1.276	2.394	.096
	Within Groups	57.047	107	.533		

Total	59.600	109			

Table 9-5:The PDP: F-value and significant value of the ANOVA analysis

		Sum of Squares	df	Mean Square	F	P Value
BE2	Between Groups	.426	2	.213	.340	.713
	Within Groups	67.029	107	.626		
	Total	67.455	109			
BE3	Between Groups	.585	2	.293	.533	.589
	Within Groups	58.770	107	.549		
	Total	59.355	109			
BE4	Between Groups	3.201	2	1.601	2.322	.103
	Within Groups	73.753	107	.689		
	Total	76.955	109			
BE5	Between Groups	.406	2	.203	.311	.733
	Within Groups	69.857	107	.653		
	Total	70.264	109			
BF1	Between Groups	1.131	2	.565	.826	.441
	Within Groups	73.242	107	.685		
	Total	74.373	109			
BF2	Between Groups	.845	2	.422	.638	.530
	Within Groups	70.828	107	.662		
	Total	71.673	109			
BG1	Between Groups	1.360	2	.680	.892	.413
	Within Groups	81.558	107	.762		
	Total	82.918	109			
BG2	Between Groups	4.037	2	2.019	3.217	.044
	Within Groups	67.135	107	.627		
	Total	71.173	109			
BG3	Between Groups	1.335	2	.668	.967	.383
	Within Groups	73.838	107	.690		
	Total	75.173	109			
BG4	Between Groups	1.734	2	.867	1.296	.278
	Within Groups	71.584	107	.669		
	Total	73.318	109			
BG5	Between Groups	.452	2	.226	.312	.733
	Within Groups	77.448	107	.724		
	Total	77.900	109			

Table 9-6: The PDP: F-value and significant value of the ANOVA analysis

BB1

L		N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a,b]	Academic and Practising Architect	49	3.76	
	Academic Architect	32	4.00	4.00
	Practising Architect	29		4.34
	Sig.		.437	.197

BG2

	L	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a,b]	Academic Architect	32	3.31	
	Academic and Practising Architect	49	3.55	3.55
	Practising Architect	29		3.83
	Sig.		.423	.316

Table 9-7: Tukey HSD Post Hoc Multiple Comparison Test

Respondents' category	No	Degree of freedom	Chi-square	Kendal's coefficient (W)	Significance
Overall	110	42	505.957	.110	0.000
Architect practising	29	42	152.294	.125	0.000
Academic and Architect practising	49	42	222.028	.108	0.000
Academic Architect	32	42	201.839	.150	0.000

Table 9-8: Kendall's Coefficient of Concordance

Code	End user factors	Reference
BA1	Utilizing views and orientation	(Dunne et al,2011)
BB1	Durable, high quality finishes	Li and Tsang (2008)
BB2	Select good colour to use	Li and Tsang (2008)
BB3	Passive spaces layout allow social interaction	(Fowler et al, 2005)
BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)	(Fowler et al, 2005) (Todd, 2001)
BE1	The adequacy of light sufficiency in spaces	(Fowler et al, 2005) (Cutler, L.J. and R.A. Kane ,2009), (Todd, 2001)
BE4	The lighting quality enhances or interferes with well-being of occupants	(Fowler et al, 2005) (WBDG Productive Committee,2011)
BG2	Utility passive design cores uniformly designed and vertically stacked	Centre For the Built Environment (NA)
BG3	Make the atrium or rotunda adequate for cleaning, maintenance etc	(Khalil and Husin, 2009)
BG4	Reduce consumption of water, energy and electricity	Zachary et al (2010), Fowler et al (2005)

Table 9-9: The top EUFs of PFP

9.3.1.3 Passive design Usability

The statistic reported in Table 9-11, which are the results of the ranking of each group; show that there is little difference or no significance between groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_3 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design usability sub-attributes: operability and human behaviour design factors" based on their professional role.

A_{03} ($p > 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design usability sub-attributes: operability and human behaviour design factors" based on their professional role.

The result of the ANOVA analysis of each EUF of PDU is as shown in Table 9-11. The ANOVA explains whether the overall P values for EUFs were significant. However, statistically there is no significant difference between architects' responses for each EUF as all of them are >.05. This confirms the null hypothesis.

ANOVA analysis shows the top 5 EUFs ranked, which are CA6, CA7, CA8, CB1 and CB2. All of them have no statistically significant differences. Table 9-10 shows these EUFs and their respective references from the literature review.

Code	End user factors	Reference
CA6	Accessible passive design controls for multiple users	Brown and Cole (2009), eMi2 (2006) and Barlex (2006) Brown et al (2010)
CA7	Design passive space that is well-suited for multi-user activities and capabilities	Nylåna (2005), Blakstad et al (2008), Brown and Cole (2009) Jensø (2011), Mitchell (2011), and eMi2 (2006)
CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)	Brown et al (2010)
CB1	Reduce user stress and feelings of frustration due to lack of space	Hansen et al (2005)
CB2	Consider safety, health and physical well-being needs for multiple users of passive buildings	Mitchell (2011), Brown et al (2010), Haron and Hamad (2011) and Hansen et al (2005)

Table 9-10: The top end user factors of passive design usability based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	P Value
CA1	Between Groups	.386	2	.193	.281	.755
	Within Groups	73.468	107	.687		
	Total	73.855	109			
CA2	Between Groups	.542	2	.271	.426	.654
	Within Groups	68.013	107	.636		
	Total	68.555	109			
CA3	Between Groups	.076	2	.038	.050	.952
	Within Groups	82.478	107	.771		
	Total	82.555	109			
CA4	Between Groups	1.007	2	.504	.647	.526
	Within Groups	83.256	107	.778		
	Total	84.264	109			
CA5	Between Groups	.618	2	.309	.437	.647
	Within Groups	75.646	107	.707		
	Total	76.264	109			
CA6	Between Groups	1.340	2	.670	1.004	.370
	Within Groups	71.432	107	.668		
	Total	72.773	109			
CA7	Between Groups	1.244	2	.622	.989	.375
	Within Groups	67.310	107	.629		
	Total	68.555	109			
CA8	Between Groups	2.327	2	1.164	2.040	.135
	Within Groups	61.027	107	.570		
	Total	63.355	109			
CB1	Between Groups	3.582	2	1.791	2.204	.115
	Within Groups	86.972	107	.813		
	Total	90.555	109			
CB2	Between Groups	1.446	2	.723	1.185	.310
	Within Groups	65.317	107	.610		
	Total	66.764	109			
CB3	Between Groups	.116	2	.058	.070	.932
	Within Groups	88.102	107	.823		
	Total	88.218	109			
CB4	Between Groups	.409	2	.205	.263	.770
	Within Groups	83.445	107	.780		
	Total	83.855	109			

Table 9-11: The PDU: The F-value and significant value of the ANOVA analysis

9.3.1.4 Passive design Flexibility

ANOVA has also been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_4 ($p > 0.05$): There is no statistically significant difference between the architect's perceptions regarding the level of effectiveness of EUFs of "passive design flexibility sub-attributes: future adaptability and flexible space" based on their professional role.

A_{04} ($p < 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design flexibility sub-attributes: future adaptability and flexible space" based on their professional role.

Each EUF has been analysed by using ANOVA. The result of this analysis is shown in Table 9-13. P value for EUF was significant. Based on analysis of the three types of professional roles there is only one EUF out of the 18 EUFs to which their responses differed significantly. That EUF was DA8. This is highlighted in Table 9-13. This explains that one of the professional roles rated that the EUFs differed significantly more than the other professional roles did. In this case, the null hypothesis is rejected.

ANOVA shows us that there is a significant difference. However, which specific means are different from others is not provided in the ANOVA analysis. For this reason, a Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. However, only DA8 was significantly different, as shown in Figure 9:14. The significant value is less than .05 and there is difference between the participants' responses.

The highest ratings of the 8 EUFs are DA2, DA8, DA10, DB1, DB2, DB3, DB5 and DB6. The description of these EUFs is shown in Table 9-13. The P-value of EUFs DA8 is 4.500, p=.013. The Post Hoc Tukey test was used to determine which professional role is different from the others. This shows there is a difference between the agreements between these factors. DA8 (Design passive space that responds to changes in spatial dimensions (volume)) has been referred to by Slaughter (2001), who referred to the volume that should be accommodating the changes. For this reason, this factor was selected as an essential EUF that responds to the changes in EU changes and needs. The EUFs were selected based on a literature review, as shown in Table 9-12.

Code	End user factors	Reference
DA2	Design passive building to adapt for dysfunctional future utilisation	Fernandez (2003), Till et al (2006), Singh et al (1999), Blok and Herwijinen (2005), WBDG Productive Committee (2009) and Finch (2009)
DA8	Design passive space that responds to changes in spatial dimensions (volume)	Slaughter, (2001)
DA10	Design passive layout based on future use scenarios	Niklas & Bengt (2009)
DB1	Specify spaces for multiple use	Finch (2009) and Fitzgerald et al (2009)
DB2	Use movable walls	Till and Schneider (2006)
DB3	Flexible access within and between passive spaces	Moharram (1980)
DB5	Use modular passive space planning strategies	Till, Jeremy and Schneider, Tatjana (2006) and Finch (2009)
DB6	Minimise partitions between passive spaces to control lighting, ventilation and thermal comfort	Moharram (1980)

Table 9-12: The top end user factors of passive design flexibility based on the F-value

		Sum of Squares	df	Mean Square	F	P Value
DA1	Between Groups	.060	2	.030	.032	.969
	Within Groups	99.840	107	.933		
	Total	99.900	109			
DA2	Between Groups	2.167	2	1.083	1.237	.294
	Within Groups	93.697	107	.876		
	Total	95.864	109			
DA3	Between Groups	1.198	2	.599	.542	.583
	Within Groups	118.292	107	1.106		
	Total	119.491	109			
DA4	Between Groups	.713	2	.356	.442	.644
	Within Groups	86.342	107	.807		
	Total	87.055	109			
DA5	Between Groups	.797	2	.398	.506	.604
	Within Groups	84.158	107	.787		
	Total	84.955	109			
DA6	Between Groups	.108	2	.054	.070	.933
	Within Groups	82.846	107	.774		
	Total	82.955	109			
DA7	Between Groups	.216	2	.108	.125	.882
	Within Groups	92.002	107	.860		
	Total	92.218	109			
DA8	Between Groups	6.960	2	3.480	4.500	.013
	Within Groups	82.758	107	.773		
	Total	89.718	109			

DA9	Between Groups	.874	2	.437	.484	.617
	Within Groups	96.544	107	.902		
	Total	97.418	109			
DA10	Between Groups	4.543	2	2.271	2.579	.081
	Within Groups	94.221	107	.881		
	Total	98.764	109			
DA11	Between Groups	.447	2	.223	.234	.791
	Within Groups	101.917	107	.952		
	Total	102.364	109			
DB1	Between Groups	1.637	2	.819	1.010	.368
	Within Groups	86.735	107	.811		
	Total	88.373	109			
DB2	Between Groups	2.144	2	1.072	1.033	.359
	Within Groups	111.029	107	1.038		
	Total	113.173	109			
DB3	Between Groups	1.771	2	.885	1.077	.344
	Within Groups	87.947	107	.822		
	Total	89.718	109			
DB4	Between Groups	1.078	2	.539	.655	.521
	Within Groups	88.022	107	.823		
	Total	89.100	109			
DB5	Between Groups	2.688	2	1.344	1.583	.210
	Within Groups	90.812	107	.849		
	Total	93.500	109			
DB6	Between Groups	2.929	2	1.464	1.673	.193
	Within Groups	93.662	107	.875		
	Total	96.591	109			
DB7	Between Groups	.718	2	.359	.410	.664
	Within Groups	93.546	107	.874		
	Total	94.264	109			

Table 9-13: The PDFL: F-value and significant value of the ANOVA analysis

DA8

	L	N	Subset for alpha = 0.05	
			1	2
Tukey HSDa,b	Practising Architect	29	3.21	
	Academic and Practising Architect	49		3.78
	Academic Architect	32		3.78
	Sig.		1.000	1.000

Table 9-14: Tukey HSD Post Hoc Multiple Comparison Test

9.3.1.5 Passive Design Reliability

ANOVA has also been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

H_5 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design reliability S-ATTs: durability, material reliability and resilient design factors" based on their professional role.

H_{05} ($p < 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design reliability S-ATTs: durability, material reliability and resilient design factors" based on their professional role.

Each EUF has been analysed by using ANOVA. The result of this analysis is shown in Table 9-16. FS value for each EUF was significant. Based on analysis of the three types of professional roles, there is only one EUF out of the 13 to which their responses differ significantly. That EUF is EB2. This is highlighted in Table 9-16. This explains that one of the professional roles rated that the EUFs differ significantly more than the other professional roles did. In this case, the null hypothesis is rejected.

ANOVA shows that there is a significant difference. However, which specific means are different from other is not provided in the ANOVA analysis. For this reason, Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. However, only the EB2 was significantly different, as shown in Table 9-17. The significant P. value is less than .05 and there is difference between the participants' responses.

The highest ratings of the 5 EUFs are EA1, EA4, EA5, EB1 and EB2. These EUFs were selected based on a literature review, as shown in Table 9-15. The F-value of EUF EB2 is 3.334, p=.039. The Post Hoc tukey test was used to determine which professional role is different from the others. This shows there is a difference in agreement between these EUFs.

Code	End user factors	Reference
EA1	Ensure the passive performance of space or element remains serviceable	Davies and Wyatt (2005)
EA4	Select components that are resistant to environmental agents	ABCB (2006)
EA5	Compatibility in joining lighting, ventilation and thermal comfort elements together	ABCB (2006)
EB1	Consider passive building joint seals to resist infiltration of moisture or deleterious materials	Wright and Frohnsdorff (1985)
EB2	Use high quality material with long service life to handle passive functions	ABCB (2006)

Table 9-15: The top end user factors of passive design reliability based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	P-Value
EA1	Between Groups	1.403	2	.701	1.194	.307
	Within Groups	62.861	107	.587		
	Total	64.264	109			
EA2	Between Groups	.135	2	.068	.121	.886
	Within Groups	59.765	107	.559		
	Total	59.900	109			
EA3	Between Groups	.026	2	.013	.020	.980
	Within Groups	67.647	107	.632		
	Total	67.673	109			
EA4	Between Groups	1.507	2	.753	1.177	.312
	Within Groups	68.457	107	.640		
	Total	69.964	109			
EA5	Between Groups	1.934	2	.967	1.344	.265
	Within Groups	76.984	107	.719		
	Total	78.918	109			
EA6	Between Groups	.908	2	.454	.668	.515
	Within Groups	72.692	107	.679		
	Total	73.600	109			
EA7	Between Groups	1.263	2	.632	.873	.421
	Within Groups	77.428	107	.724		
	Total	78.691	109			
EB1	Between Groups	2.011	2	1.006	1.196	.306
	Within Groups	89.953	107	.841		
	Total	91.964	109			
EB2	Between Groups	5.202	2	2.601	3.334	.039
	Within Groups	83.489	107	.780		
	Total	88.691	109			
EB3	Between Groups	.670	2	.335	.454	.636
	Within Groups	79.002	107	.738		
	Total	79.673	109			
EB4	Between Groups	.078	2	.039	.033	.968

	Within Groups	125.886	107	1.177		
	Total	125.964	109			
EC1	Between Groups	1.151	2	.575	.707	.495
	Within Groups	87.040	107	.813		
	Total	88.191	109			
EC2	Between Groups	1.032	2	.516	.655	.521
	Within Groups	84.286	107	.788		
	Total	85.318	109			

Table 9-16: The F-value and significant value of the ANOVA analysis

EB2

	L	N	Subset for alpha = 0.05	
			1	2
Tukey HSDa,b	Academic Architect	32	3.88	
	Academic and Practising Architect	49	4.06	4.06
	Practising Architect	29		4.45
	Sig.		.654	.165

Table 9-17: Tukey HSD Post Hoc Multiple Comparison Test

9.3.1.6 Passive design Maintainability

The statistic is reported in Table 9-19. The result of ranking of each group shows that there are little differences or no significance between groups. For this reason ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_6 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design maintainability S-ATTs: standardisation, material and accessibility design factors" based on their professional role.

A_{06} ($p < 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design maintainability S-ATTs: standardisation, material and accessibility design factors" based on their professional role.

The result of ANOVA analysis of each EUFs of PDM is shown in Table 9-19. The ANOVA explains whether the overall FS values for EUFs were significant. However, statistically there is no significant difference between architects' responses for each EUF, because all of them have a P >.05. This confirms that null hypothesis.

ANOVA analysis shows the top 7 EUFs ranked, which are (FA2, FA4, FB2, FB3, FC1, FC2 and FC4), as shown in Table 9-19. All of them have no statistically significant differences. All of these EUFs were selected based on a literature review, as shown in Table 9-18.

Code	End user factors	Reference
FA2	Simplify interface of passive design elements and building façade	NASA (2008), Haiquan et al (2011), Wani et al (1999), Mohammed and Hassanain (2010) and Crow (2002)
FA4	Utilize non-destructive disassembly passive design strategies	NASA (2008)
FB2	Locate lighting, ventilation and thermal comfort materials for operability to minimise degradation	NAS (2008)
FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity	Wood (2005), De Silva et al (2004) and Dunston et al (1999)
FC1	The cleanliness and maintenance of passive spaces enhances or interferes with well-being of occupants	Solana et al (2005)
FC2	The interior of the passive building is designed to be easy to clean and maintain	NASA (2008) and Chew et al (2004)
FC4	Critical lighting, ventilation and thermal comfort element should be visible for inspection	Lin (2010)

Table 9-18: The top end user factors of passive design maintainability based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	P-Value
FA1	Between Groups	1.408	2	.704	.761	.470
	Within Groups	98.965	107	.925		
	Total	100.373	109			
FA2	Between Groups	1.266	2	.633	1.017	.365
	Within Groups	66.634	107	.623		
	Total	67.900	109			
FA3	Between Groups	.019	2	.009	.011	.989
	Within Groups	91.154	107	.852		
	Total	91.173	109			
FA4	Between Groups	2.145	2	1.072	1.523	.223
	Within Groups	75.355	107	.704		
	Total	77.500	109			
FA5	Between Groups	.399	2	.200	.262	.770
	Within Groups	81.455	107	.761		
	Total	81.855	109			
FA6	Between Groups	.108	2	.054	.081	.922
	Within Groups	71.565	107	.669		
	Total	71.673	109			
FA7	Between Groups	.096	2	.048	.068	.934
	Within Groups	75.577	107	.706		
	Total	75.673	109			
FA8	Between Groups	1.291	2	.645	.800	.452
	Within Groups	86.382	107	.807		
	Total	87.673	109			
FA9	Between Groups	1.146	2	.573	.558	.574
	Within Groups	109.945	107	1.028		
	Total	111.091	109			
FB1	Between Groups	1.809	2	.904	.880	.418
	Within Groups	109.909	107	1.027		
	Total	111.718	109			
FB2	Between Groups	1.691	2	.846	1.190	.308
	Within Groups	76.027	107	.711		
	Total	77.718	109			
FB3	Between Groups	2.096	2	1.048	1.827	.166
	Within Groups	61.368	107	.574		
	Total	63.464	109			
FC1	Between Groups	2.757	2	1.378	1.764	.176
	Within Groups	83.616	107	.781		
	Total	86.373	109			
FC2	Between Groups	1.520	2	.760	1.139	.324
	Within Groups	71.398	107	.667		
	Total	72.918	109			
FC3	Between Groups	.524	2	.262	.341	.712
	Within Groups	82.167	107	.768		
	Total	82.691	109			
FC4	Between Groups	2.900	2	1.450	2.451	.091
	Within Groups	63.291	107	.592		
	Total	66.191	109			
FC5	Between Groups	.545	2	.272	.510	.602
	Within Groups	57.128	107	.534		
	Total	57.673	109			
FC6	Between Groups	.162	2	.081	.094	.911
	Within Groups	92.529	107	.865		
	Total	92.691	109			
FC7	Between Groups	.358	2	.179	.236	.790
	Within Groups	81.106	107	.758		
	Total	81.464	109			

Table 9-19: The PDM: The F-value and significant value of the ANOVA analysis

9.4 Analysis of participants' responses based on their experience

Participants' experience has been divided into three main categories. The first category is 0-5 years' experience, the second category is 5-10 years' experiences and the last category is more than 10 years' experience. Based on the analysis the total number of respondents for each category is illustrated in Table 9-20.

Years' Experience							
0-5 Years		5-10 Years		More than 10 Years		Total	
No	Percentage	No	Percentage	No	Percentage	No	Mean
33	30%	23	20.9%	54	49.1%	110	100%

Table 9-20: Respondents' classification based on their experience

For this reason, their results will be compared based on the average rating, then it will be ranked and the hypothesis will be tested through it. Kendall's coefficient can help to measure the agreement between the categories of professional role as well as between the rankings of EUFs. 0 means no agreement and 1 perfect agreement, and concordance is .061 and 108 for the three categories. The lowest value of Kendall's coefficient refers to the weak agreement between the respondents. However, there is still agreement between them. There is a difference between the values of significant level for each group, as shown in Table 9-21. The value for the group with more than 10 years' experience is P=0.000. This means the null hypothesis has to be rejected. The values for the group with 0-5 years' experience and the group with 5-10 years' experience are .005 and .117 respectively. This means the null hypothesis has to be accepted.

Respondents' category	No	Degree of freedom	Chi-square	Kendall's coefficient (W)	Significance
Overall	110	18	124.043	.063	.000
0-5 years	33	18	36.908	.062	.005
5-10years	23	18	25.283	.061	.117
More than 10 years	54	18	105.271	.108	.000

Table 9-21: Kendall's Coefficient of Concordance

9.4.1 ANOVA Testing Based on Architects' Experience

9.4.1.1 Passive Design Functionality

ANOVA has also been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_1 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design functionality S-ATTs: site, orientation and vegetation, building form, space planning, roof and façade" based on their experience.

A_{01} ($p < 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design functionality S-ATTs: site, orientation and vegetation, building form, space planning, roof and façade" based on their experience.

Each EUF has been analysed by using ANOVA. The result of this analysis is shown in Tables 9-23 and 9-24. FS value for EUF was significant. Based on analysis of the three types of years of experience, responses for only four EUFs out of the 43 differed significantly. These four EUFs were AA2, AC11, AC12 and AE9. This is highlighted in Tables 9-23 and 9-24. This explains that one of the years of experience groups has rated the EUFs significantly different compared to the other years of experience groups. In this case, the null hypothesis is rejected.

ANOVA shows us that there is a significant difference. However, which specific means are different from others is not provided in the ANOVA analysis. For this reason, Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. However, only AA2, AC11, AC12 and AE9 were significantly different, as shown in Tables 9-23 and 9-24. The significance value is less than .05 and there is a difference between the participants' responses. The highest ratings of the 11 EUFs are AA2, AC1, AC4, AC6, AC11, AC12, AE5, AE7, AE8, AE9 and AE11. Each EUF is explained in Table 9-22. The P-values of the four EUFs (AA2 AC11, AC12 and AE9) are F=3.946, p=.022, F (3.799), p=.025, F (3.242), p=.043 and F (3.389), p=.037 respectively. The Post Hoc Tukey test, as shown in Table 9-25, was used to determine which years of experience group is different from the others. This shows that there is a difference in agreement between these EUFs; even though the P value of the AC12 EUF in Table 9-23 shows it is less than .05; The Post Hoc Tukey test illustrates that there is no significant difference. Orient the building is one of the strict EUFs, without which the PDF cannot be successful. In Table 9-22 there are several authors who paid attention to these EUFs. However, the experience of the architect can affect the ranking or assessment of this EUF. For example, the Ministry for the Environment (2008) referred to how the narrow floor can have an effect on optimising lighting. In addition to that, the interior zone can lead to maximising the storage of heating or not (City of Santa Barbara Community Development Department, 2006 and United States Department of Energy, 2000). The importance of space area is in its degree of effectiveness on optimising lighting, ventilation and thermal comfort. The perspectives of architects based on their experience are different. For this reason, providing tools or methods that can help the designers at various levels to meet EU needs becomes essential. The knowledge and awareness could play a clear role in assessment of these EUFs.

Code	End user factors	Reference
AA2	Orient the building for optimum lighting, ventilation and thermal comfort	United States Department of Energy (2000), BIM (2011) and Ministry for the Environment (2008)
AC1	Subdivide interior to create separate heating and cooling zones	Ministry for the Environment (2008) and Department of Education, Northern Ireland (DENI) and corp creator (1998)
AC4	Provide vertical air shafts/stacks, and central exhaust paths to promote interior airflow	United States Department of Energy (2000)
AC6	The proportion of the plan is long and narrow (use linear plan form, or a similar strategy) to optimise day lighting	Ministry for Environment (1998-2011)
AC11	Narrow floor width to optimise natural ventilation	Ministry for the Environment (2008)
AC12	Provide solar-oriented interior zone to store and maximise solar heat gain	City of Santa Barbara Community Development Department (2006) and United States Department of Energy (2000)
AE5	Locate thermal mass inside the envelope to store heating	City of Santa Barbara Community Development Department (2006) and United States Department of Energy (2000)
AE7	Use solar wall on south-oriented surfaces	Kurtbas and Durmus (2008)
AE8	Develop details to minimise air infiltration and ex-filtration	Ministry for the Environment (2008)
AE9	Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort	Franco (2007)

AE11	Use exterior elements to direct summer wind flow into the interior	Bateson and Hoare Lea (2001

Table 9-22: The top end user factors of passive design functionality based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	P-Value
AA1	Between Groups	.559	2	.279	.306	.737
	Within Groups	97.805	107	.914		
	Total	98.364	109			
AA2	Between Groups	6.009	2	3.005	3.946	.022
	Within Groups	81.482	107	.762		
	Total	87.491	109			
AA3	Between Groups	2.245	2	1.122	1.233	.296
	Within Groups	97.428	107	.911		
	Total	99.673	109			
AB1	Between Groups	3.304	2	1.652	1.768	.176
	Within Groups	100.014	107	.935		
	Total	103.318	109			
AB2	Between Groups	2.068	2	1.034	.886	.415
	Within Groups	124.851	107	1.167		
	Total	126.918	109			
AB3	Between Groups	2.596	2	1.298	1.544	.218
	Within Groups	89.958	107	.841		
	Total	92.555	109			
AB4	Between Groups	.522	2	.261	.296	.745
	Within Groups	94.351	107	.882		
	Total	94.873	109			
AC1	Between Groups	4.666	2	2.333	2.429	.093
	Within Groups	102.789	107	.961		
	Total	107.455	109			
AC2	Between Groups	1.448	2	.724	.964	.385
	Within Groups	80.406	107	.751		
	Total	81.855	109			
AC3	Between Groups	.761	2	.381	.558	.574
	Within Groups	72.912	107	.681		
	Total	73.673	109			
AC4	Between Groups	2.789	2	1.395	1.892	.156
	Within Groups	78.883	107	.737		
	Total	81.673	109			
AC5	Between Groups	.244	2	.122	.144	.866
	Within Groups	90.628	107	.847		
	Total	90.873	109			
AC6	Between Groups	3.463	2	1.731	1.890	.156
	Within Groups	98.001	107	.916		
	Total	101.464	109			
AC7	Between Groups	.424	2	.212	.335	.716
	Within Groups	67.839	107	.634		
	Total	68.264	109			
AC8	Between Groups	1.814	2	.907	1.157	.318
	Within Groups	83.859	107	.784		
	Total	85.673	109			
AC9	Between Groups	.717	2	.358	.715	.492
	Within Groups	53.647	107	.501		
	Total	54.364	109			
AC10	Between Groups	1.744	2	.872	1.539	.219
	Within Groups	60.628	107	.567		
	Total	62.373	109			
AC11	Between Groups	6.721	2	3.360	3.799	.025
	Within Groups	94.634	107	.884		
	Total	101.355	109			
AC12	Between Groups	4.549	2	2.274	3.242	.043
	Within Groups	75.051	107	.701		
	Total	79.600	109			
AC13	Between Groups	.537	2	.269	.301	.741
	Within Groups	95.654	107	.894		
	Total	96.191	109			
AC14	Between Groups	.005	2	.002	.003	.997
	Within Groups	75.713	107	.708		
	Total	75.718	109			
AD1	Between Groups	.744	2	.372	.734	.482
	Within Groups	54.175	107	.506		
	Total	54.918	109			

Table 9-23: The PDF: The F-value and significant value of the ANOVA analysis

		Sum of Squares	df	Mean Square	F	P-Value
AD2	Between Groups	1.665	2	.832	1.517	.224
	Within Groups	58.699	107	.549		
	Total	60.364	109			
AD3	Between Groups	.992	2	.496	.596	.553
	Within Groups	89.008	107	.832		
	Total	90.000	109			
AD4	Between Groups	1.104	2	.552	.694	.502
	Within Groups	85.159	107	.796		
	Total	86.264	109			
AD5	Between Groups	1.371	2	.685	.975	.380
	Within Groups	75.184	107	.703		
	Total	76.555	109			
AD6	Between Groups	.614	2	.307	.352	.704
	Within Groups	93.286	107	.872		
	Total	93.900	109			
AE1	Between Groups	.467	2	.234	.336	.715
	Within Groups	74.296	107	.694		
	Total	74.764	109			
AE2	Between Groups	1.420	2	.710	1.117	.331
	Within Groups	67.999	107	.636		
	Total	69.418	109			
AE3	Between Groups	1.688	2	.844	1.105	.335
	Within Groups	81.730	107	.764		
	Total	83.418	109			
AE4	Between Groups	.601	2	.300	.329	.721
	Within Groups	97.772	107	.914		
	Total	98.373	109			
AE5	Between Groups	1.989	2	.995	1.782	.173
	Within Groups	59.729	107	.558		
	Total	61.718	109			
AE6	Between Groups	2.240	2	1.120	1.258	.288
	Within Groups	95.224	107	.890		
	Total	97.464	109			
AE7	Between Groups	2.567	2	1.283	2.102	.127
	Within Groups	65.333	107	.611		
	Total	67.900	109			
AE8	Between Groups	4.329	2	2.165	2.172	.119
	Within Groups	106.625	107	.996		
	Total	110.955	109			
AE9	Between Groups	4.974	2	2.487	3.389	.037
	Within Groups	78.517	107	.734		
	Total	83.491	109			
AE10	Between Groups	1.079	2	.540	.684	.507
	Within Groups	84.412	107	.789		
	Total	85.491	109			
AE11	Between Groups	2.865	2	1.432	1.782	.173
	Within Groups	86.008	107	.804		
	Total	88.873	109			
AE12	Between Groups	1.215	2	.608	.927	.399
	Within Groups	70.139	107	.656		
	Total	71.355	109			
AE13	Between Groups	.668	2	.334	.434	.649
	Within Groups	82.387	107	.770		
	Total	83.055	109			
AE14	Between Groups	1.006	2	.503	.781	.460
	Within Groups	68.894	107	.644		
	Total	69.900	109			
AE15	Between Groups	.154	2	.077	.101	.904
	Within Groups	81.300	107	.760		
	Total	81.455	109			
AE16	Between Groups	1.158	2	.579	.832	.438
	Within Groups	74.442	107	.696		
	Total	75.600	109			

Table 9-24: The PDF: The F-value and significant value of the ANOVA analysis

AA2

Tukey HSD[a,b]

M	N	Subset for alpha = 0.05	
		1	2
0-5 Years	33	4.18	
5-10 Years	23	4.48	4.48
More than 10 years	54		4.72
Sig.		.361	.500

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 32.503.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

AC11

Tukey HSD[a,b]

M	N	Subset for alpha = 0.05	
		1	2
0-5 Years	33	3.09	
More than 10 years	54	3.59	3.59
5-10 Years	23		3.70
Sig.		.085	.898

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 32.503.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

AC12

Tukey HSD[a,b]

M	N	Subset for alpha = 0.05
		1
0-5 Years	33	3.55
5-10 Years	23	3.70
More than 10 years	54	4.00
Sig.		.078

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 32.503.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

AE9

Tukey HSD[a,b]

M	N	Subset for alpha = 0.05	
		1	2
5-10 Years	23	3.96	
0-5 Years	33	4.24	4.24
More than 10 years	54		4.50
Sig.		.373	.449

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 32.503.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 9-25: Tukey HSD Post Hoc Multiple Comparison Test

9.4.1.2 Passive Design performance

ANOVA also has been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_2 (p > 0.05): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design performance S-ATTs: site performance, space performance, thermal comfort performance, natural ventilation performance, day lighting performance, acoustic performance and adequacy and consumption strategies design factors" based on their experience.

A_{02} (p < 0.05): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design performance S-ATTs: site performance, space performance, thermal comfort performance, natural ventilation performance, day lighting performance, acoustic performance and adequacy and consumption strategies design factors" based on their experience.

Each EUF has been analysed by using ANOVA. The result of this analysis is shown in Tables 9-27 and 9-28. Fs value for EUF was significant. Based on analysis of the three types of years of experience, the responses for only one EUF out of the 27 were significantly different. This EUF is BE3. This is highlighted in Table 9-27, which explains that one of the years of experience groups rated the EUFs significantly different compared to the other groups. In this case, the null hypothesis is rejected.
ANOVA shows us that there is a significant difference. However, which specific means are different from the others is not provided in the ANOVA analysis. For this reason, a Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. However, only the BE3 was not significantly different, as shown in Table 9-29, even though the P value is less than .05 and there is difference between the participants' responses. The highest ratings of the 8 EUFs are BA2, BB4, BD1, BD2, BD3, BE2, BE3 and BF2. The descriptions of these EUFs are shown in Table 9-26. The F-value of the BE3 EUF is F=3.387, p=.037. The Post Hoc Tukey test was used to determine which years of experience group is different from the others. This shows there is a difference in agreement about these EUFs, even though Fowler et al (2005) and Khalil and Husin (2009) referred to these EUFs, as illustrated in Table 9-26. Visual comfort is an essential EUF and is related to EU comfort. Also, this EUF is related to the design function and performance. It is expected because the majority of the designers concentrate on the functions more than the effectiveness of lighting.

Code	End user factors	Reference
BA2	Affect site on visual focus	Dunne et al (2011)
BB4	Provide a special character for the space based on building type	Montague (2007)
BD1	A comfortable internal air temperature	Fowler et al (2005) and Gossauer and Wagner (2007)
BD2	The air quality in space enhances or interferes with well-being of occupants	Fowler et al (2005)
BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)	Fowler et al (20050 and Todd (2001)
BE2	The adequacy of natural light in spaces	Hassanain (2011) and Fowler et al (2005)
BE3	The visual comfort of the lighting (e.g., glare, reflections, contrast)	Fowler et al (2005) and Khalil and Husin (2009)
BF2	Utilize good acoustic conditions	Fowler et al (2005)

Table 9-26: The top end user factors of passive design performance based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	P-Value
BA1	Between Groups	.443	2	.222	.455	.636
	Within Groups	52.111	107	.487		
	Total	52.555	109			
BA2	Between Groups	1.809	2	.905	1.298	.277
	Within Groups	74.564	107	.697		
	Total	76.373	109			
BA3	Between Groups	1.052	2	.526	.675	.511
	Within Groups	83.321	107	.779		
	Total	84.373	109			
BB1	Between Groups	.147	2	.073	.098	.906
	Within Groups	79.817	107	.746		
	Total	79.964	109			
BB2	Between Groups	.778	2	.389	.558	.574
	Within Groups	74.640	107	.698		
	Total	75.418	109			
BB3	Between Groups	.085	2	.043	.062	.940
	Within Groups	73.333	107	.685		
	Total	73.418	109			
BB4	Between Groups	2.911	2	1.455	1.751	.179
	Within Groups	88.944	107	.831		
	Total	91.855	109			
BB5	Between Groups	.232	2	.116	.129	.879
	Within Groups	96.323	107	.900		
	Total	96.555	109			
BB6	Between Groups	.274	2	.137	.177	.838
	Within Groups	82.680	107	.773		
	Total	82.955	109			
BB7	Between Groups	.417	2	.208	.314	.731
	Within Groups	71.047	107	.664		
	Total	71.464	109			
BC1	Between Groups	.677	2	.339	.549	.579
	Within Groups	66.014	107	.617		
	Total	66.691	109			
BC2	Between Groups	.163	2	.082	.123	.884
	Within Groups	70.928	107	.663		
	Total	71.091	109			
BD1	Between Groups	2.150	2	1.075	2.782	.066
	Within Groups	41.341	107	.386		
	Total	43.491	109			
BD2	Between Groups	1.457	2	.728	1.598	.207
	Within Groups	48.762	107	.456		
	Total	50.218	109			
BD3	Between Groups	.956	2	.478	.905	.408
	Within Groups	56.535	107	.528		
	Total	57.491	109			
BE1	Between Groups	.410	2	.205	.371	.691
	Within Groups	59.190	107	.553		
	Total	59.600	109			
BE2	Between Groups	3.575	2	1.788	2.994	.054
	Within Groups	63.879	107	.597		
	Total	67.455	109			
BE3	Between Groups	3.534	2	1.767	3.387	.037
	Within Groups	55.821	107	.522		
	Total	59.355	109			
BE4	Between Groups	.113	2	.057	.079	.924
	Within Groups	76.841	107	.718		
	Total	76.955	109			
BE5	Between Groups	.344	2	.172	.263	.769
	Within Groups	69.920	107	.653		
	Total	70.264	109			
BF1	Between Groups	.401	2	.201	.290	.749
	Within Groups	73.972	107	.691		
	Total	74.373	109			
BF2	Between Groups	1.619	2	.809	1.236	.295
	Within Groups	70.054	107	.655		
	Total	71.673	109			

Table 9-27: The PDP: The F-value and significant value of the ANOVA analysis

		Sum of Squares	df	Mean Square	F	**P-Value**
BG1	Between Groups	.164	2	.082	.106	.900
	Within Groups	82.754	107	.773		
	Total	82.918	109			
BG2	Between Groups	.395	2	.197	.298	.743
	Within Groups	70.778	107	.661		
	Total	71.173	109			
BG3	Between Groups	.565	2	.282	.405	.668
	Within Groups	74.608	107	.697		
	Total	75.173	109			
BG4	Between Groups	.851	2	.425	.628	.536
	Within Groups	72.468	107	.677		
	Total	73.318	109			
BG5	Between Groups	.165	2	.082	.113	.893
	Within Groups	77.735	107	.726		
	Total	77.900	109			

Table 9-28: The PDP: The F-value and significant value of the ANOVA analysis

BE3

	M	N	Subset for alpha = 0.05
			1
Tukey HSD[a,b]	0-5 Years	33	4.06
	5-10 Years	23	4.13
	More than 10 years	54	4.44
	Sig.		.086

Table 0-29: Tukey HSD Post Hoc Multiple Comparison Test

9.4.1.3 Passive design usability

ANOVA has also been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_3 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design usability S-ATTs: operability and human behaviour design factors" based on their experience.

A_{03}($p < 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design usability S-ATTs: operability and human behaviour design factors" based on their experience.

Each EUF has been analysed by using ANOVA. The result of this analysis is shown in Table 9-31. Fs value for EUF was significant. Based on analysis of the three types of years of experience, the responses for only one EUF out of the 12 differed significantly. The EUF is CA2. This is highlighted in Table 9-31. This explains that one of the years of experience groups rated that the EUFs differ significantly more than other groups did. In this case, the null hypothesis is rejected.

ANOVA shows us that there is a significant difference. However, which specific means are different from the others is not provided in the ANOVA analysis. For this reason, a Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. However, only the CA2 was significantly different, as shown in Figure 9-32. The significant value is less than .05 and there is difference between the participants' responses.

The highest ratings of the 5 EUFs are CA2, CA5, CA6, CA7 and CB4. The F-values of the CA2 EUF is F=4.478, p=.014. The Post Hoc Tukey test was used to determine which years of experience group is different from the others. This shows there is a difference in agreement between these EUFs. CA2 (Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas) has been referred to by Nylåna (2005). As shown in Table 9-30, even though these EUFs are and effective EUF based the litrature rreview, there is a difference between the different respondents' views. From the researcher's point of view, the human scale is one of the principles that the designer should take into account for any design. The result was not expected at all because it is not related to experience but is related to the foundations of the building.

Code	End user factors	Reference
CA2	Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	Nylåna (2005)
CA5	Incorporate passive design technologies which are easy to operate by multiple users	Nylåna (2005) and Brown and Cole (2009)
CA6	Accessible passive design controls for multiple users	Brown and Cole (2009),eMi2 (2006) Barlex (2006) and Brown et al (2010)
CA7	Design passive space that is well-suited for multi-user activities and capabilities	Nylåna (2005), Blakstad et al (2008), Brown and Cole (2009) Jensø (2011), Mitchell (2011) and eMi2 (2006)
CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)	Brown et al (2010)
CB4	Consider users' cultural image, identity, lifestyle, psychological needs and perceptions in line with passive lighting, ventilation and thermal comfort strategies	Blakstad et al (2008) and Hansen et al (2005)

Table 9-30: The top end user factors of passive design usability based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	P-Value
CA1	Between Groups	1.211	2	.606	.892	.413
	Within Groups	72.643	107	.679		
	Total	73.855	109			
CA2	Between Groups	5.295	2	2.647	4.478	.014
	Within Groups	63.260	107	.591		
	Total	68.555	109			
CA3	Between Groups	.095	2	.047	.062	.940
	Within Groups	82.460	107	.771		
	Total	82.555	109			
CA4	Between Groups	1.139	2	.569	.733	.483
	Within Groups	83.125	107	.777		
	Total	84.264	109			
CA5	Between Groups	2.321	2	1.161	1.680	.191
	Within Groups	73.942	107	.691		
	Total	76.264	109			
CA6	Between Groups	2.080	2	1.040	1.574	.212
	Within Groups	70.693	107	.661		
	Total	72.773	109			
CA7	Between Groups	2.918	2	1.459	2.378	.098
	Within Groups	65.637	107	.613		
	Total	68.555	109			
CA8	Between Groups	.278	2	.139	.236	.790
	Within Groups	63.076	107	.589		
	Total	63.355	109			
CB1	Between Groups	.242	2	.121	.143	.867
	Within Groups	90.312	107	.844		

	Total	90.555	109			
CB2	Between Groups	.381	2	.190	.307	.736
	Within Groups	66.383	107	.620		
	Total	66.764	109			
CB3	Between Groups	1.138	2	.569	.699	.499
	Within Groups	87.080	107	.814		
	Total	88.218	109			
CB4	Between Groups	2.797	2	1.399	1.846	.163
	Within Groups	81.057	107	.758		
	Total	83.855	109			

Table 9-31: The F-value and significant value of the ANOVA analysis

CA2

	M	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a,b]	5-10 Years	23	3.57	
	0-5 Years	33	3.88	3.88
	More than 10 years	54		4.13
	Sig.		.232	.390

Table 9-32: Tukey HSD Post Hoc Multiple Comparison Test

9.4.1.4 Passive Design Flexibility

ANOVA has also been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_4 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design flexibility S-ATTs: future adaptability and flexible space" based on their experience.

A_{04}($p < 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design flexibility S-ATTs: future adaptability and flexible space" based on their experience.

Each EUF has been analysed by using ANOVA. The result of this analysis is shown in Table 9-34. FS value for EUF was significant. Based on analysis of the three types of years of experience, the responses for only one EUF out of the 18 differed significantly. That EUF is DA10. This is highlighted in Table 9-34. This explains that one of the years of experience groups rated the EUFs significantly different more than the other groups did. In this case, the null hypothesis is rejected.

ANOVA shows us that there is a significant difference. However, which specific means are different from the others is not provided in the ANOVA analysis. For this reason, a Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. However, only DA10 was significantly different, as shown in Table 9-35. The significant value is less than .05 and there is difference between the participants' responses.

The highest ratings of the 5 EUFs are DA3, DA7, DA10, DB1 and DB2. The F-values of the DA10 EUF are F=3.551, p=.032. The Post Hoc Tukey test was used to determine which years of experience group is different from the others. This shows there is a difference in agreement between these EUFs. Considering future scenarios is one of the EUFs that should be considered when designing a space (Niklas & Bengt, 2009), as shown in Table 9-33. The designer should take this factor into account, in order to meet EU needs. However, this result is reasonable because the flexibility ATT is the lowest ranked ATT in terms of designers keeping the EU in their mind when they design PDFL.

Code	End user factors	Reference
DA3	Allow ample floor-to-floor height for future modification	City of New York (1999), IBEC (2008) and Saari and Heikkilä (2008)
DA7	Design a passive building that responds to the increasing pressures of rapid changes in technology shifts	Niklas and Bengt (2009) and Finch (2009)
DA10	Design passive layout based on future use scenarios	Niklas and Bengt (2009)
DB1	Specify spaces for multiple use	Finch (2009) and Fitzgerald et al (2009)
DB2	Use movable walls	Till and Schneider (2006)

Table 9-33: The top end user factors of passive design flexibility based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	P-Value
DA1	Between Groups	.247	2	.124	.133	.876
	Within Groups	99.653	107	.931		
	Total	99.900	109			
DA2	Between Groups	2.147	2	1.073	1.226	.298
	Within Groups	93.717	107	.876		
	Total	95.864	109			
DA3	Between Groups	4.244	2	2.122	1.970	.144
	Within Groups	115.247	107	1.077		
	Total	119.491	109			
DA4	Between Groups	1.241	2	.620	.774	.464
	Within Groups	85.814	107	.802		
	Total	87.055	109			
DA5	Between Groups	.274	2	.137	.173	.841
	Within Groups	84.680	107	.791		
	Total	84.955	109			
DA6	Between Groups	.294	2	.147	.190	.827
	Within Groups	82.661	107	.773		
	Total	82.955	109			
DA7	Between Groups	4.666	2	2.333	2.851	.062
	Within Groups	87.553	107	.818		
	Total	92.218	109			
DA8	Between Groups	.617	2	.308	.370	.691
	Within Groups	89.101	107	.833		
	Total	89.718	109			
DA9	Between Groups	.293	2	.147	.162	.851
	Within Groups	97.125	107	.908		
	Total	97.418	109			
DA10	Between Groups	6.147	2	3.074	3.551	.032
	Within Groups	92.617	107	.866		
	Total	98.764	109			
DA11	Between Groups	1.762	2	.881	.937	.395
	Within Groups	100.601	107	.940		
	Total	102.364	109			
DB1	Between Groups	2.370	2	1.185	1.474	.234
	Within Groups	86.003	107	.804		
	Total	88.373	109			
DB2	Between Groups	3.061	2	1.531	1.487	.231
	Within Groups	110.111	107	1.029		
	Total	113.173	109			
DB3	Between Groups	.846	2	.423	.509	.602
	Within Groups	88.872	107	.831		
	Total	89.718	109			
DB4	Between Groups	.729	2	.364	.441	.644
	Within Groups	88.371	107	.826		
	Total	89.100	109			

DB5	Between Groups	1.793	2	.896	1.046	.355
	Within Groups	91.707	107	.857		
	Total	93.500	109			
DB6	Between Groups	.710	2	.355	.396	.674
	Within Groups	95.881	107	.896		
	Total	96.591	109			
DB7	Between Groups	.489	2	.245	.279	.757
	Within Groups	93.775	107	.876		
	Total	94.264	109			

Table 9-34: The F-value and significant value of the ANOVA analysis

DA10

Tukey HSD[a,b]

M	N	Subset for alpha = 0.05
		1
0-5 Years	33	3.45
5-10 Years	23	3.74
More than 10 years	54	4.00
Sig.		.052

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 32.503.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 9-35: Tukey HSD Post Hoc Multiple Comparison Test

9.4.1.5 Passive Design Reliability

ANOVA also has been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

H_5 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design reliability S-ATTs: durability, material reliability and resilient design factors" based on their experience.

H_{05} ($p < 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design reliability S-ATTs: durability, material reliability and resilient design factors" based on their experience.

Each EUF has been analysed by using ANOVA. The result of this analysis is shown in Table 9-37. P-value for EUF was significant. Based on analysis of the three types of years of experience, the responses for only one EUF out of the 13 differed significantly. That EUF is EB3. This is highlighted in Table 9-37. This explains that one of the years of experience groups rated that the EUFs differ significantly more than the other groups did. In this case, the null hypothesis is rejected.

ANOVA shows us that there is a significant difference. However, which specific means are different from others is not provided in the ANOVA analysis. For this reason, a Post Hoc Multiple

Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. However, only the EB3 was significantly different, as shown in Table 9-38. The significant value is less than .05 and there is a difference between the participants' responses.

The highest ratings of the 5 EUFs are EA2, EA6, EB2, EB3 and EC2. The F-values of the EB3 EUF is F=3.378, p=.038. The Post Hoc Tukey test was used to determine which years of experience group is different from the others. This shows there is a difference between the agreements between these EUFs. ABCB (2006) referred to the issue of contraction and expansion of material, as shown in Table 9-36. The design should consider this in terms of the area and material expansion. The difference between the architects' perspectives is possible because this issue is related to the construction and material field more than to the design. The designers' experience can have an effect on realising the effectiveness of this EUF.

Code	End user factors	Reference
EA2	Provide optimum drainage and venting to minimise accumulation of moisture	PERD (1997)
EA6	Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation	ABCD (2006) and PERD (1997)
EB2	Use high quality material with long service life to handle passive functions	ABCB (2006)
EB3	Consider the rate of expansion / contraction of material of passive design strategies	ABCB (2006)
EC2	Passive building fabric should be adaptable to cyclic change	PERD (1997), Balcomb (1992) and Mital et al (2007)

Table 9-36: The top end user factors of passive design reliability based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
EA1	Between Groups	.933	2	.467	.788	.457
	Within Groups	63.330	107	.592		
	Total	64.264	109			
EA2	Between Groups	2.079	2	1.040	1.924	.151
	Within Groups	57.821	107	.540		
	Total	59.900	109			
EA3	Between Groups	.143	2	.071	.113	.893
	Within Groups	67.530	107	.631		
	Total	67.673	109			
EA4	Between Groups	1.882	2	.941	1.479	.232
	Within Groups	68.081	107	.636		
	Total	69.964	109			
EA5	Between Groups	1.632	2	.816	1.130	.327
	Within Groups	77.286	107	.722		
	Total	78.918	109			
EA6	Between Groups	2.450	2	1.225	1.842	.163
	Within Groups	71.150	107	.665		
	Total	73.600	109			
EA7	Between Groups	.340	2	.170	.232	.793
	Within Groups	78.351	107	.732		
	Total	78.691	109			
EB1	Between Groups	1.813	2	.906	1.076	.345
	Within Groups	90.151	107	.843		
	Total	91.964	109			
EB2	Between Groups	3.584	2	1.792	2.253	.110
	Within Groups	85.107	107	.795		
	Total	88.691	109			
EB3	Between Groups	4.731	2	2.366	3.378	.038
	Within Groups	74.941	107	.700		
	Total	79.673	109			
EB4	Between Groups	.254	2	.127	.108	.898

	Within Groups	125.710	107	1.175		
	Total	125.964	109			
EC1	Between Groups	.417	2	.208	.254	.776
	Within Groups	87.774	107	.820		
	Total	88.191	109			
EC2	Between Groups	2.518	2	1.259	1.627	.201
	Within Groups	82.800	107	.774		
	Total	85.318	109			

Table 9-37: The PDR: The F-value and significant value of the ANOVA analysis

EB3

	M	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a,b]	5-10 Years	23	3.65	
	0-5 Years	33	3.82	3.82
	More than 10 years	54		4.15
	Sig.		.704	.255

Table 9-38: Tukey HSD Post Hoc Multiple Comparison Test

9.4.1.6 Passive Design Maintainability

ANOVA also has been used to test the EUFs of this ATT. Also, the result of ranking in the previous chapters shows that there are some differences between architects' groups. For this reason the ANOVA method has been used to justify the group responses through testing the following hypotheses:

A_0 ($p > 0.05$): There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design maintainability S-ATTs: standardisation, material and accessibility design factors" based on their experience.

A_1 ($p < 0.05$): There is a statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design maintainability S-ATTs: standardisation, material and accessibility design factors" based on their experience.

Each EUF has been analysed by using ANOVA. The result of this analysis is shown in Table 9-40. FS value for EUF was significant. Based on analysis of the three types of years of experience, the responses for only one EUF out of the 19 differed significantly. That EUF is FA7. This is highlighted in Table 9-40. This explains that one of the years of experience groups rated that the EUFs differ significantly more than the other years of experience groups did. In this case, the null hypothesis is rejected.

ANOVA shows us that there is a significant difference. However, which specific means are different from the others is not provided in the ANOVA analysis. For this reason, a Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. However, only the FA7 was significantly different, as shown in Table 9-41. The significant value is less than .05 and there is difference between the participants' responses.

The highest ratings of the 5 EUFs are FA6, FA7, FA9, FB2 and FB3, as explained in Table 9-39. The F-values of the FA7 EUF is F=5.753, p=.004. The Post Hoc Tukey test was used to determine which years of experience group is different from the others. This shows there is a difference in agreement between these EUFs. Ease of adjusting the components and elements has been referred to by the Northumberland National Park Authority (2006). This issue could be neglected by the designers because it is raised after the building has been constructed and is in use. In the design stage, it could be considered if the designer has a high level of awareness and knowledge, which means designer experience.

Code	End user factors	Reference
FA6	Design for ease to remove or replace lighting, ventilation and thermal comfort elements	ARIS (1995), Chew et al (2004) and NASA (2008)
FA7	Design for ease to adjust lighting, ventilation and thermal comfort physical element features	Northumberland National Park Authority (2006)
FA9	Provide passive design strategies that minimise the time for maintenance	NASA (2008).
FB2	Locate lighting, ventilation and thermal comfort materials for operability to minimise degradation	NASA (2008
FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity	Wood (2005), De Silva et al 92004) and Dunston et al (1999)

Table 9-39: The top end user factors of passive design maintainability based on the F-value

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
FA1	Between Groups	1.698	2	.849	.921	.401
	Within Groups	98.675	107	.922		
	Total	100.373	109			
FA2	Between Groups	.095	2	.047	.075	.928
	Within Groups	67.805	107	.634		
	Total	67.900	109			
FA3	Between Groups	.473	2	.237	.279	.757
	Within Groups	90.700	107	.848		
	Total	91.173	109			
FA4	Between Groups	.707	2	.353	.492	.613
	Within Groups	76.793	107	.718		
	Total	77.500	109			
FA5	Between Groups	2.397	2	1.199	1.614	.204
	Within Groups	79.457	107	.743		
	Total	81.855	109			
FA6	Between Groups	3.544	2	1.772	2.783	.066
	Within Groups	68.129	107	.637		
	Total	71.673	109			
FA7	Between Groups	7.347	2	3.674	5.753	.004
	Within Groups	68.325	107	.639		
	Total	75.673	109			
FA8	Between Groups	.764	2	.382	.470	.626
	Within Groups	86.909	107	.812		
	Total	87.673	109			
FA9	Between Groups	5.537	2	2.768	2.806	.065
	Within Groups	105.554	107	.986		
	Total	111.091	109			
FB1	Between Groups	.881	2	.441	.425	.655
	Within Groups	110.837	107	1.036		
	Total	111.718	109			
FB2	Between Groups	3.121	2	1.560	2.238	.112
	Within Groups	74.598	107	.697		
	Total	77.718	109			
FB3	Between Groups	2.804	2	1.402	2.473	.089
	Within Groups	60.659	107	.567		
	Total	63.464	109			
FC1	Between Groups	.220	2	.110	.137	.873
	Within Groups	86.153	107	.805		
	Total	86.373	109			

FC2	Between Groups	1.311	2	.655	.979	.379
	Within Groups	71.607	107	.669		
	Total	72.918	109			
FC3	Between Groups	.095	2	.047	.061	.941
	Within Groups	82.596	107	.772		
	Total	82.691	109			
FC4	Between Groups	.180	2	.090	.146	.864
	Within Groups	66.011	107	.617		
	Total	66.191	109			
FC5	Between Groups	.062	2	.031	.058	.944
	Within Groups	57.610	107	.538		
	Total	57.673	109			
FC6	Between Groups	2.764	2	1.382	1.644	.198
	Within Groups	89.927	107	.840		
	Total	92.691	109			
FC7	Between Groups	1.128	2	.564	.751	.474
	Within Groups	80.335	107	.751		
	Total	81.464	109			

Table 9-40: The PDM: F-value and significant value of the ANOVA analysis

FA7

M		N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a,b]	5-10 Years	23	3.74	
	0-5 Years	33	3.85	3.85
	More than 10 years	54		4.31
	Sig.		.846	.053

Table 9-41: Tukey HSD Post Hoc Multiple Comparison Test

9.5 Analysis of participants' respondents based on their professional role for the second part of the questionnaire

ANOVA also has been used to test the PDHAs for the second part of the questionnaire. The ANOVA method has been used to justify the group responses through testing the following hypotheses:

B_1: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF based on their professional role.

B_{01}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF based on their professional role.

B_2: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDP based on their professional role.

B_{02}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDP based on their professional role.

B_3: There is no obvious difference between the architects' perception regarding the rate of considering EU aspirations during design PDU based on their professional role.

B_{03}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDU based on their professional role.

B_4: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDFL based on their professional role.

B_{04}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDFL based on their professional role.

B_5: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDR based on their professional role.

B_{05}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDR based on their professional role.

B_5: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDM based on their professional role.

B_{05}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDM based on their professional role.

The result of this analysis is shown in Table 9-42. P-value for the PDHAs was significant. Based on analysis of the three types of professional role, responses were significantly different for only one PDHA out of the 6. That PDHAs is PDU. This is highlighted in Table 9-42. This explains that one of the professional roles rated that the ATT differed significantly more than the other professional groups did. In this case, the null hypothesis is rejected.

ANOVA shows us that there is a significant difference. However, which specific means are different from others is not provided in the ANOVA analysis. For this reason, a Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. Even though PDU was significantly different, as shown in Table 9-42, the significant value is less than .05 and there is difference between the participants' responses. The result of the Tukey test shows that there is no significant difference, as shown in Table 9-43.This ATT was selected based on ISO 9126 as well as because it was reviewed as part of the literature review (see Chapter 6). The result was unexpected.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
GA	Between Groups	1.050	2	.525	2.335	.102
	Within Groups	24.050	107	.225		
	Total	25.100	109			
GB	Between Groups	.783	2	.391	1.262	.287
	Within Groups	33.181	107	.310		
	Total	33.964	109			
GC	Between Groups	2.038	2	1.019	3.415	.036
	Within Groups	31.926	107	.298		
	Total	33.964	109			
GD	Between Groups	.764	2	.382	1.018	.365
	Within Groups	40.154	107	.375		
	Total	40.918	109			
GG	Between Groups	.712	2	.356	.890	.414
	Within Groups	42.779	107	.400		
	Total	43.491	109			
GF	Between Groups	.193	2	.097	.226	.798

Within Groups	45.770	107	.428			
Total	45.964	109				

Table 9-42: The F-value and significant value of the ANOVA analysis

GD

Tukey B[a,b]

L	N	Subset for alpha = 0.05
		1
Academic Architect	32	2.31
Practising Architect	29	2.41
Academic and Practising Architect	49	2.51

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 34.827.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 9-43: Tukey HSD Post Hoc Multiple Comparison Test

9.6 Analysis of participants' responses based on their experience for the second part of the questionnaire

ANOVA also has been used to test the PDHAs for the second part of the questionnaire. ANOVA method has been used to justify the group responses through testing the following hypotheses:

B_1: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF based on their experience.

B_{01}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDF based on their experience.

B_2: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDP based on their experience.

B_{02}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDP based on their experience.

B_3: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDU based on their experience.

B_{03}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDU based on their experience.

B_4: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDFL based on their experience.

B_{04}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDFL based on their experience.

B_5: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDR based on their experience.

B_{05}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDR based on their experience.

B_5: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDM based on their experience.

B_{05}: There is an obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDM based on their experience.

The result of this analysis is shown in Table 9-44. P-value for PDHAs was significant. Based on analysis of the three types of years of experience groups, the responses for 3 PDHAs out of the 6 differ significantly. These PDHAs namely are PDP, PDU and PDFL. This is highlighted in Table 9-44. This explains that one of the professional roles rated that the ATT differed significantly more than the other professional group did. In this case, the null hypothesis is rejected.

ANOVA shows us that there is a significant difference. However, which specific means are different from others is not provided in the ANOVA analysis. For this reason, a Post Hoc Multiple Comparison Test has been conducted. The sample size is uneven; for this reason a Tukey test was done. Even though PDU was significantly different, as shown in Table 9-44, the significant value is less than .05 and there is difference between the participants' responses. The result of the Tukey test shows that there are significant differences, as shown in Table 9-45.The three ATTs were selected based on ISO 9126 as well as the fact that they had been reviewed based on the literature review (see Chapters 5, 6 and 7). The result was unexpected.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
GA	Between Groups	1.289	2	.645	2.897	.060
	Within Groups	23.811	107	.223		
	Total	25.100	109			
GB	Between Groups	3.405	2	1.702	5.961	.004
	Within Groups	30.559	107	.286		
	Total	33.964	109			
GC	Between Groups	2.709	2	1.355	4.638	.012
	Within Groups	31.254	107	.292		
	Total	33.964	109			
GD	Between Groups	4.376	2	2.188	6.406	.002
	Within Groups	36.543	107	.342		
	Total	40.918	109			
GG	Between Groups	1.727	2	.864	2.213	.114
	Within Groups	41.764	107	.390		
	Total	43.491	109			
GF	Between Groups	1.376	2	.688	1.651	.197
	Within Groups	44.588	107	.417		
	Total	45.964	109			

Table 9-44: The F-value and significant value of the ANOVA analysis

GB

Tukey B[a,b]

M	N	Subset for alpha = 0.05	
		1	2
0-5 Years	33	2.42	
5-10 Years	23	2.48	
More than 10 years	54		2.80

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 32.503.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

GC
Tukey B[a,b]

M	N	Subset for alpha = 0.05	
		1	2
0-5 Years	33	2.45	
5-10 Years	23	2.48	
More than 10 years	54		2.78

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 32.503.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

GD
Tukey B[a,b]

M	N	Subset for alpha = 0.05	
		1	2
0-5 Years	33	2.21	
5-10 Years	23	2.26	
More than 10 years	54		2.63

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 32.503.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 9-45: Tukey HSD Post Hoc Multiple Comparison Test

9.6.1 Reliability

Reliability testing is a method to test the reliability of EUFs for checking the possibility of grouping them together. This test has been used to test the grouping of EUFs in each S-ATT. Cronbach's alpha was used to check the reliability of the grouping EUFs. The scale of this method is shown in the following table:

	Internal consistency
$\alpha \geq 0.9$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Table 9-46: Cronbach's alpha (George and Mallery, 2003, p. 231).

Based on Table 9-46, if the grouping EUF is more than .5, that classifies a reliable group; and if it is less than five this means it is an unreliable group.

9.6.1.1 Reliability Testing of Passive Design Functionality:

Reliability analysis was used to analyse EUFs of PDF to test the possibility of grouping the EUFs into S-ATTs. This analysis is done by computing Cronbach's alpha, as shown in Table 9-47, where S-ATTs: AA (Site orientation and vegetation), AB (Building form), AC (Space planning), AD (Roof strategies) and AE (Façade) are more than 0.50, which is considered to be more reliable. The Cronbach's alpha of the total ATT is .929, which is generally reliable. The Cronbach's alpha of the attributes is the highest one of the six ATTs.

Code		End User factors of Passive Design Functionality	Cronbach's Alpha if Item Deleted	Cronbach's Alpha for sub-attribute	Cronbach's Alpha for the whole attribute
AA	AA1	Use vegetation for optimum lighting, ventilation and thermal comfort	.640	.618	.929
	AA2	Orient the building for optimum lighting, ventilation and thermal comfort	.415		
	AA3	Use nearby landforms and structures for wind protection and summer shading	.490		
AB	AB1	Design compact building form for optimum heating and ventilation	.445	.593	
	AB2	Use low mass construction to allow rapid heat-up or cooling of structure	.600		
	AB3	Shape the building to maximise exposure to [winter sun and summer breezes]	.424		
	AB4	Use high mass construction with appropriate insulation to promote night ventilation	.598		
AC	AC1	Subdivide interior to create separate heating and cooling zones	.790	.789	
	AC2	Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	.777		
	AC3	Use central atriums, courtyards and lobbies (elevators, and stairs can be locate in central areas) for optimum ventilation	.780		
	AC4	Provide vertical air shafts/stacks, and central exhaust paths to promote interior airflow	.765		
	AC5	Use open plan interior to promote interior airflow	.771		
	AC6	The proportion of the plan is long and narrow (use linear plan form, or a similar strategy) to optimise day lighting	.776		
	AC7	Organise rooms, corridors, stairwells in a way that uploads a low resistance airflow path through the building	.772		
	AC8	Consider interior surface colours and finishes for optimum day lighting	.775		
	AC9	Design plan to create buffer zones from the summer radiation	.780		
	AC10	Plan specific spaces or functions to coincide with solar orientation	.778		
	AC11	Narrow floor width to optimise natural ventilation	.780		
	AC12	Provide solar-oriented interior zone to store and maximise solar heat gain	.777		
	AC13	Attenuate plan to promote ventilation	.773		
	AC14	Link the exterior and interior airflows by single-sided, cross or stack ventilation	.772		
AD	AD1	Use roof elements for stack effect ventilation	.656	.673	
	AD2	Use skylight, light tube and clerestory for natural illumination	.666		
	AD3	Use solar roof collectors on the south-oriented surfaces	.634		
	AD4	Use double roof and wall construction for ventilation within envelope	.589		
	AD5	Use ventilated roof to lower summer gains through roof	.620		
	AD6	Use of an appropriate shape and angle of the roof for optimum ventilation and thermal comfort	.615		
AE	AE1	Minimise the ratio of exterior surfaces to interior floor areas	.852	.855	
	AE2	Use high-capacitance materials to store solar heat gain and control heat flow through envelope	.843		
	AE3	Optimise south-facing glazing	.846		
	AE4	Use Trombe wall or double façade to collect solar gain	.849		
	AE5	Locate thermal mass inside the envelope to store heating	.848		
	AE6	Minimise openings in envelope to reduce thermal gain	.846		
	AE7	Use solar wall on south-oriented surfaces	.843		
	AE8	Develop details to minimise air infiltration and ex-filtration	.847		
	AE9	Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort	.846		
	AE10	Use louvred wall for maximum ventilation control	.850		
	AE11	Use exterior elements to direct summer wind flow into the interior	.844		
	AE12	Orient openings to facilitate natural ventilation	.842		
	AE13	Details openings to limit undesired air infiltration and ex-filtration as well as to reduce convective gains	.843		
	AE14	Provide light shelves to allow daylight to penetrate deep into a building	.849		
	AE15	Use higher window to wall area ratios to maximise solar access and ventilation	.855		
	AE16	Provide high levels of insulation in the façade and building envelope to reduce summer conductive gain and to preserve internal heat	.846		

Table 9-47: Cronbach’s Alpha of the passive design functionality survey

9.6.1.2 Reliability Testing of Passive Design Performance:

Reliability analysis was used to analyse EUFs of PDP to test the possibility of grouping the EUFs into S-ATTs. This analysis is done by computing Cronbach's alpha, as shown in Table 9-48, where 7 S-ATTs (BA, BB, BC, BD, BE, BF and BG), namely: site performance, space performance, natural ventilation, lighting, thermal comfort, acoustic and adequacy consumption and strategies, are more than

0.50, which is considered to be reliable. The Cronbach's alpha of the total ATTs is .928, which is generally reliable. The Cronbach's alpha of the ATT is the second highest one of the six ATTs.

Code		End User factors of Passive Design Performance	Cronbach's Alpha if Item Deleted	Cronbach's Alpha for sub-attribute	Cronbach's Alpha for the whole attribute
BA	BA1	Utilizing views and orientation	.765	.753	.928
	BA2	Affect site on visual focus	.536		
	BA3	Enhancement of site to consider identity	.673		
BB	BB1	Durable, high quality finishes	.792	.822	
	BB2	Select good colour to use	.817		
	BB3	Passive spaces layout allow social interaction	.796		
	BB4	Provide a special character for the space based on building type	.784		
	BB5	Space layout allows for security, way finding, and flexibility of use	.783		
	BB6	Space layout enhances or interferes with well-being of occupants	.819		
	BB7	The adequacy of passive design space available for function/activities	.790		
BC	BC1	The temperature controls provide for the needs of different occupants	0	.562	
	BC2	Thermal comfort in spaces enhances or interferes with well-being of occupants	0		
BD	BD1	A comfortable internal air temperature	.666	.783	
	BD2	The air quality in space enhances or interferes with well-being of occupants	.668		
	BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)	.786		
BE	BE1	The adequacy of light sufficiency in spaces	.685	.738	
	BE2	The adequacy of natural light in spaces	.666		
	BE3	The visual comfort of the lighting (e.g., glare, reflections, contrast)	.697		
	BE4	The lighting quality enhances or interferes with well-being of occupants	.656		
	BE5	Atrium or rotunda control devices for optimum space comfort	.748		
BF	BF1	Select insulation against noises from corridors to give space privacy	0	.758	
	BF2	Utilize good acoustic conditions	0		
BG	BG1	The horizontal utility systems of passive building logically configured to serve multi-user needs	.725	.774	
	BG2	Utility passive design cores uniformly designed and vertically stacked	.713		
	BG3	Make the atrium or rotunda adequate for cleaning, maintenance etc	.741		
	BG4	Reduce consumption of water, energy and electricity	.757		
	BG5	Response time to urgent repair issues	.728		

Table 9-48: Cronbach's Alpha of the passive design performance of the UCPBD survey

9.6.1.3 Reliability Testing of Passive Design Usability

Reliability analysis was used to analyse EUFs of PDU to test the possibility of grouping the EUFs into S-ATTs. This analysis is done by computing Cronbach's alpha, as shown in Table 9-49, where two S-ATTs (CA and CB), namely operability and human behaviour, are more than 0.50, which is considered to be more reliable. The Cronbach's alpha of the total ATTs is .859, which is generally reliable. The Cronbach's alpha of this ATT is more than 0.50. This means the ATT is reliable.

Code		End User factors of Passive Design Usability	Cronbach's Alpha if Item Deleted	Cronbach's Alpha for sub-attribute	Cronbach's Alpha for the whole Attribute
CA	CA1	Optimum position of service and passive element or equipment for operability	.814	.832	.859
	CA2	Consider the dimensions of passive spaces to suit human scale (avoiding under-size or oversize areas)	.808		
	CA3	Group homogeneous passive functions together for efficient operability	.803		
	CA4	Avoid slopes and steps of passive space floors	.841		
	CA5	Incorporate passive design technologies which are easy to operate by multiple users	.811		
	CA6	Accessible passive design controls for multiple users	.807		
	CA7	Design passive space that is well-suited for multi-user activities and capabilities	.801		
	CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)	.813		
CB	CB1	Reduce user stress and feelings of frustration due to lack of space	.725	.726	

	CB2	Consider safety, health and physical well-being needs for multiple users of passive buildings	.598		
	CB3	Consider different sensing, smelling, hearing, feeling and seeing of users in passive space design	.613		
	CB4	Consider users' cultural image, identity, lifestyle, psychological needs and perceptions in line with passive lighting, ventilation and thermal comfort strategies	.714		

Table 9-49: Cronbach's Alpha of the passive design usability of the UCPBD survey

9.6.1.4 Reliability Testing of Passive Design Flexibility

Reliability analysis was used to analyse EUFs of PDFL to test the possibility of grouping the EUFs into S-As. This analysis is done by computing Cronbach's alpha, as shown in Table 9-50, where 2 S-ATTs (DA and DB), namely Future adaptability and Flexible space, are more than 0.50, which is considered to be more reliable. The Cronbach's alpha of the total ATTs is .925, which is generally reliable. The Cronbach's alpha of this ATT is more than 0.50. This means the ATT is reliable.

Code		End User factors of Passive Design Flexibility	Cronbach's Alpha if Item Deleted	Cronbach's Alpha for sub-attribute	Cronbach's Alpha for the whole attribute
DA	DA1	Passive building structure should be upgradable for future regulations and safety procedures	.885	.896	.925
	DA2	Design passive building to adapt for dysfunctional future utilisation	.882		
	DA3	Allow ample floor-to-floor height for future modification	.887		
	DA4	Consider the passive design that accommodates fundamental changes in user preferences	.887		
	DA5	Design the passive space to cope with changes in flow of users	.886		
	DA6	Provide horizontal and vertical circulation and spaces of passive design that encompass future expansion options	.878		
	DA7	Design a passive building that responds to the increasing pressures of rapid changes in technology shifts	.889		
	DA8	Design passive space that responds to changes in spatial dimensions (volume)	.884		
	DA9	Design passive space to respond to changes in climate conditions	.896		
	DA10	Design passive layout based on future use scenarios	.889		
	DA11	Select the passive building form for change without changing the skeleton	.886		
DB	DB1	Specify spaces for multiple use	.837	.853	
	DB2	Use movable walls	.822		
	DB3	Flexible access within and between passive spaces	.829		
	DB4	The ability to subdivide large passive design spaces	.823		
	DB5	Use modular passive space planning strategies	.816		
	DB6	Minimise partitions between passive spaces to control lighting, ventilation and thermal comfort	.863		
	DB7	Design passive space to incorporate completely new functions	.837		

Table 9-50: Cronbach's Alpha of the passive design flexibility of the UCPBD survey

9.6.1.5 Reliability Testing of Passive Design Reliability

Reliability analysis was used to analyse EUFs of PDR to test the possibility of grouping the EUFs into S-ATTs. This analysis is done by computing Cronbach's alpha, as shown in Table 9-51, where 3 S-ATTs (EA, EB and EC), namely Durability, Material Reliability and Resilience are more than 0.50, which is considered to be more reliable. The Cronbach's alpha of the total attribute is .899, which is generally reliable. The Cronbach's alpha of this ATT is more than 0.50. This means the ATT is reliable.

Code	End User factors of Passive Design Reliability	Cronbach's Alpha if Item Deleted	Cronbach's Alpha for sub-attribute	Cronbach's Alpha for the whole attribute

EA	EA1	Ensure the passive performance of space or element remains serviceable	.813	.842	.899
	EA2	Provide optimum drainage and venting to minimise accumulation of moisture	.810		
	EA3	Design passive service life to match user needs	.820		
	EA4	Select components that are resistant to environmental agents	.833		
	EA5	Compatibility in joining lighting, ventilation and thermal comfort elements together	.834		
	EA6	Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation	.813		
	EA7	Protect sensitive passive elements from accidental change	.819		
EB	EB1	Consider passive building joint seals to resist infiltration of moisture or deleterious materials	.674	.752	
	EB2	Use high quality material with long service life to handle passive functions	.681		
	EB3	Consider the rate of expansion / contraction of material of passive design strategies	.627		
	EB4	Use standardisation of passive design elements and materials	.792		
EC	EC1	Specify passive space strategies for user behaviour usage (such as heavy use, accidental impact and interior humidity)	0	.738	
	EC2	Passive building fabric should be adaptable to cyclic change	0		

Table 9-51: Cronbach's Alpha of the passive design reliability of the UCPBD survey

9.6.1.6 Reliability Testing of Passive Design Maintainability

Reliability analysis was used to analyse S-ATTs of PDM to test the possibility of grouping the EUFs into S-ATTs. This analysis is done by computing Cronbach's alpha, as shown in Table 9-52, where 3 S-As (FA, FB and FC), namely Standardisation, Material and Accessibility are more than 0.50, which is considered to be more reliable. The Cronbach's alpha of the total ATTs is .925, which is generally reliable. The Cronbach's alpha of this ATT is the same with PDFL.

Code		End User factors of Passive Design Maintainability	Cronbach's Alpha if Item Deleted	Cronbach's Alpha for sub-attribute	Cronbach's Alpha for the whole attribute
FA	FA1	Provide lighting and ventilation in expected maintenance areas	.821	.845	.925
	FA2	Simplify interface of passive design elements and building façade	.829		
	FA3	Specify simple shape of both building form and space of passive design	.837		
	FA4	Utilize non-destructive disassembly passive design strategies	.839		
	FA5	Eliminate poor detailing of passive design space or element	.834		
	FA6	Design for ease to remove or replace lighting, ventilation and thermal comfort elements	.817		
	FA7	Design for ease to adjust lighting, ventilation and thermal comfort physical element features	.826		
	FA8	Design for ease of installing lighting, ventilation and thermal comfort element or material	.813		
	FA9	Provide passive design strategies that minimise the time for maintenance	.840		
FB	FB1	Minimise use of unique materials of passive design strategies	.726	.696	
	FB2	Locate lighting, ventilation and thermal comfort materials for operability to minimise degradation	.473		
	FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity	.615		
FC	FC1	The cleanliness and maintenance of passive spaces enhances or interferes with well-being of occupants	.878	.894	
	FC2	The interior of the passive building is designed to be easy to clean and maintain	.875		
	FC3	Access routes of passive space for transport of maintenance materials	.878		
	FC4	Critical lighting, ventilation and thermal comfort element should be visible for inspection	.881		
	FC5	All elements of the external passive building shell should be easy to access for maintenance and cleaning	.879		
	FC6	Optimise sizes for passive design openings for workmanship access	.875		
	FC7	Locate passive design elements where they are accessible for maintenance and repair	.882		

Table 9-52: Cronbach's Alpha of the passive design maintainability of UCPBD survey

9.6.2 Discussion

This chapter has reviewed the findings from the questionnaire on the effectiveness of the EUFs of the UCPBD conceptual model. Based on this study, it is clear that there is a difference between the architects' views based on their professional role and experience, as shown in the previous sections. The rejected factors are summarised in Table 9-53:

Areas of disagreement

ATTs	Analysis based on Professional role	Analysis based on Years of Experience
PDF	-	AA2,AC11,AC12,AE9
PDP	BB1 and BG2	BE3
PDU	-	CA2
PDFL	DA8	DA10
PDR	EB2	EB3
PDM	-	FA7

Table 9-53: Comparison of the rejected factors for both participants' professional role and experience based on the degree of significance of Anova analysis

The view between the two groups is different in terms of the highest F-values EUFs. Their views agree about F-values of some EUFs and differ about others, as highlighted in Table 9-54.

ATTs	Analysis based on Professional role	Analysis based on Years of Experience
PDF	AB2,AC6,AC8,AC9,AC12, AD2,AD5,AD6,AE11,AE16	AA2,AC1,AC4,AC6,AC11,AC12,AE5, AE7,AE8,AE9 and AE11
PDP	BA1,BB1,BB2,BB3,BD3,BE1,BE4,BG2, BG3,BG4	BA2,BB4,BD1,BD2,BD3,BE2,BE3, BF2
PDU	CA6,CA7,CA8,CB1,CB2	CA2,CA5,CA6,CA7,CB4
PDFL	DA2,DA8,DA10,DB1,DB2,DB3,DB5,D B6	DA3,DA7,DA10,DB1 DB2
PDR	EA1,EA4,EA5,EB1,EB2	EA2,EA6,EB2,EB3 EC2
PDM	FA2,FA4,FB2,FB3,FC1,FC2, FC4	FA6,FA7,FA9,FB2 FB3

Table 9-54: Comparison of the rejected factors for both participants' professional role and experience based on the F-values of Anova analysis

From this study, the rejected hypotheses are 13 EUFs out of the total of 132 EUFs, which reflects the effectiveness of the EUFs that have been selected. This reflects to what extent the EUFs can have a clear influential role during the PBD process. In addition, not considering the rejected EUF can enable the designer to meet EU needs and reduce their complaints at the early stage.

The reliability testing shows the 22 S-ATTs that are reliable, as shown in Table 9-54. Also, it has been testing the reliability for each ATTs all of them more reliable, as shown in Table 9-55. This result and the other chapters of data analysis will be discussed in detail in the discussion chapters.

ATTs	Reliable S-ATTs	Unreliable S-ATTs	Reliable ATTs	Unreliable ATTs
PDF	AA, AB, AC, AD and AE	-	√	--
PDP	BA, BB, BC, BD, BE, BF and BG	-	√	--
PDU	CA and CB	--	√	--
PDFL	DA and DB	--	√	--
PDR	EA, EB and EC	--	√	--
PDM	FA, FB and FC	-	√	--

Table 9-55: The rest of the testing reliability of the survey for both ATTs and S-ATTs

Chapter Ten: Data Reduction

10.1 Introduction:

The previous chapters have shown the differences between the levels of effectiveness in terms of the overall ranking or based on each ATT or S-ATT. The ranking was based on the level of effectiveness starting from 1 as the highest effectiveness EUFs to 132 which means the lowest effectiveness EUFs. Then one-third of the 132, which is 44 EUFs, was extracted to be the representative EUFs of the set of data. To achieve this aim, data reduction techniques were used to reduce a huge amount of data to a framework that is easy to read and understand (Norusis, 2000). After reducing the data, it will be grouped into several clusters that involve the highest effective EUFs out of the total number of EUFs (132) which are used the research questionnaire. The EUFs of each cluster are classified and arranged based on their relationship with each other. Understanding the new clusters could have a positive impact when designers design PBD in order to meet EU needs and to reduce complaints. The methodology that has been used to reduce and cluster the data will be illustrated in the following sections.

10.2 Methodology

The data analysis has been carried out by statistical analysis which includes 5 main methods: mean value, standard deviation, scale ranking, coefficient of variation, Severity Index, and ANOVAs, for comparison based on the architects' professional role and experience of EUFs for each ATT and overall for the UCPBD model. Both SPSS and Excel programs were used for the analysis index as introduced in Chapters 7, 8 and 9. Reduction of data is considered to be an important process to decrease the existing 132 EUFs and select the most effective EUFs. SPSS helps the researcher to remove the lowest effective f EUFs. This is done through using analysis of the EUFs as well as of the redundant data. The redundant data was the method used to reduce the number of EUFs. The remaining EUFs are 33 components that can be representative of UCPBD. They are categorised into 6 clusters, as will be introduced at the end of this chapter. The following sections will analyse each cluster and the 33 components. The process of the analysis is illustrated in Figure 10:4. Through the SPSS analysis, the EUFs have been reduced to 44. The clusters have been classified and the EUFs have been reduced by using SPSS. The clusters of EUFs are based on their correlation to each other. The result of this classification is illustrated in Figure 10:4. The findings and discussion of the process will be discussed in detail in the following sections.

10.3 Factor analysis

As has been referred to in the previous chapters, the EUFs of UCPBD will be ranked based on their level of effectiveness, which is, of course, based on the designers' (architects') views. The main reason to use the EUF analysis is to combine highly correlated EUFs. The EUF analysis method (SPSS 12.0.1 for Windows) is used to identify the small numbers of the EUFs. It is a series method to cluster and identify EUFs that are correlated to each other to modify them into an easy framework (Norusis, 2000). The components' methods are to extract the variables. The components include several matrices that show the relationship between the EUFs in order to find the components that need to be selected. The following sections will illustrate the EUFs of UCPBD.

10.4 Findings analysis

In factor analysis, the first phase is to find the strength correlation between the variables (Shen and Liu, 2003). The correlation coefficients matrix should be extracted then the Eigen value that is more than 1 should be highlighted from the matrix of correlation. Thirdly, the rotated components should be generated in order to identify the highest effective EUFs. This research has investigated the correlation between EUFs of UCPBD. The result of the EUF analysis is presented in Table 10-1.

Total Variance Explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Total	Total	% of Variance	Cumulative %	Total
1	38.286	29.005	29.005	38.286	29.005	29.005	9.265
2	5.121	3.880	32.885	5.121	3.880	32.885	6.313
3	4.445	3.367	36.252	4.445	3.367	36.252	5.450
4	4.161	3.152	39.404	4.161	3.152	39.404	7.554
5	3.550	2.690	42.094	3.550	2.690	42.094	4.837
6	3.290	2.492	44.586	3.290	2.492	44.586	3.390
7	2.900	2.197	46.783	2.900	2.197	46.783	10.055
8	2.848	2.157	48.941	2.848	2.157	48.941	4.751
9	2.641	2.000	50.941	2.641	2.000	50.941	7.976
10	2.605	1.974	52.915	2.605	1.974	52.915	6.664
11	2.488	1.885	54.800	2.488	1.885	54.800	6.781
12	2.300	1.743	56.542	2.300	1.743	56.542	4.566
13	2.223	1.684	58.227	2.223	1.684	58.227	8.027
14	2.129	1.613	59.840	2.129	1.613	59.840	9.031
15	2.074	1.571	61.411	2.074	1.571	61.411	5.206
16	1.966	1.490	62.901	1.966	1.490	62.901	8.462
17	1.870	1.417	64.318	1.870	1.417	64.318	7.643
18	1.751	1.327	65.644	1.751	1.327	65.644	5.223
19	1.692	1.282	66.927	1.692	1.282	66.927	9.938
20	1.668	1.263	68.190	1.668	1.263	68.190	7.388
21	1.621	1.228	69.418	1.621	1.228	69.418	9.378
22	1.563	1.184	70.602	1.563	1.184	70.602	9.071
23	1.528	1.158	71.760	1.528	1.158	71.760	4.861
24	1.476	1.118	72.878	1.476	1.118	72.878	3.361
25	1.401	1.061	73.939	1.401	1.061	73.939	5.587
26	1.345	1.019	74.959	1.345	1.019	74.959	7.117
27	1.307	.990	75.949	1.307	.990	75.949	9.908
28	1.264	.957	76.906	1.264	.957	76.906	4.028
29	1.208	.916	77.822	1.208	.916	77.822	6.286
30	1.181	.895	78.717	1.181	.895	78.717	7.014
31	1.113	.843	79.560	1.113	.843	79.560	2.579

32	1.093	.828	80.387	1.093	.828	80.387	10.726
33	1.076	.815	81.202	1.076	.815	81.202	6.019
34	0.998						
35	0.983						
36	0.943						
130	-1.439E-015	-1.090E-015	100.000				
131	-1.711E-015	-1.296E-015	100.000				
132	-2.192E-015	-1.660E-015	100.000				

Table 10-1: Total variance explained

In the previous table the EUFs have been set according to their relation to each other. The first column is classified as initial Eigen values that are related to the Eigen value of the matrix correlation. The Eigen value is defined as “the variances of the factors”. This is because the EUFs of PBD have been carried out on the correlation matrix. It is also illustrates which factors remain to be analysed. For factor analysis, the EUFs with an Eigen value more than 1 have been selected, which includes 33 EUFs. The percentage of total variance of the first 33 components is 81.202%, as shown in the commutative columns. This means the 33 EUFs can be considered as the representative EUFs out of the total 132 EUFs of UCPBD. *“Eigen value is the amount of the total test variance that is accounted for by a particular factor, the total variance for each test being unity (100%)”* (Vakili-Ardebili ,2004,p.112). The Eigen value in the first column for the second factor is 5.121, which is accounted for by 132 EUFs that mean 5.121:132=3.880%. Based on this method of analysis, the factors that have been selected are 33 EUFs. The proportion of them is 81.202%. Also, all of them are more than 1. The next group of columns (Extraction Sum of Squared Loadings) is the sum of the squared loadings for an unrotated factor solution. The last column is the rotation.

10.5 Scree plot

There is another method that can help the researcher to investigate the total of most effective factors. This is presented in Figures 10:1, 10:2 and 10:3. The Scree plot presents the EUFs of the Eigen Value for each EUF (component) based on inserted data. The slope of the Scree is towards to the points that are less than 1. Based on the first figure, the factor that is more than one is between 34 and 35 EUFs. After these points it seems to be horizontal. To investigate the exact point, the grid has been edited horizontally and vertically by SPSS program, as shown in Figures 10:2 and 10:3, to identify the exact point that is more than 1. For this, the 33 components which are more than 1 have been identified, as shown in Figure 10:1.

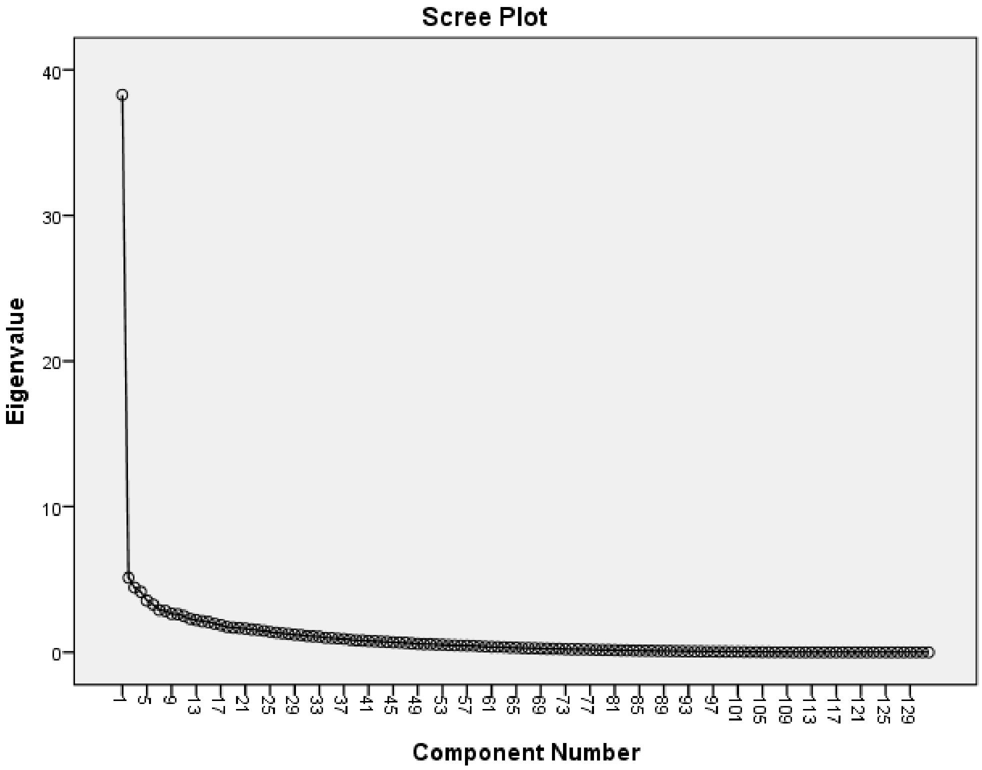


Figure 10:0:1: Scree Plot of 132 Eco-indicators of the Study

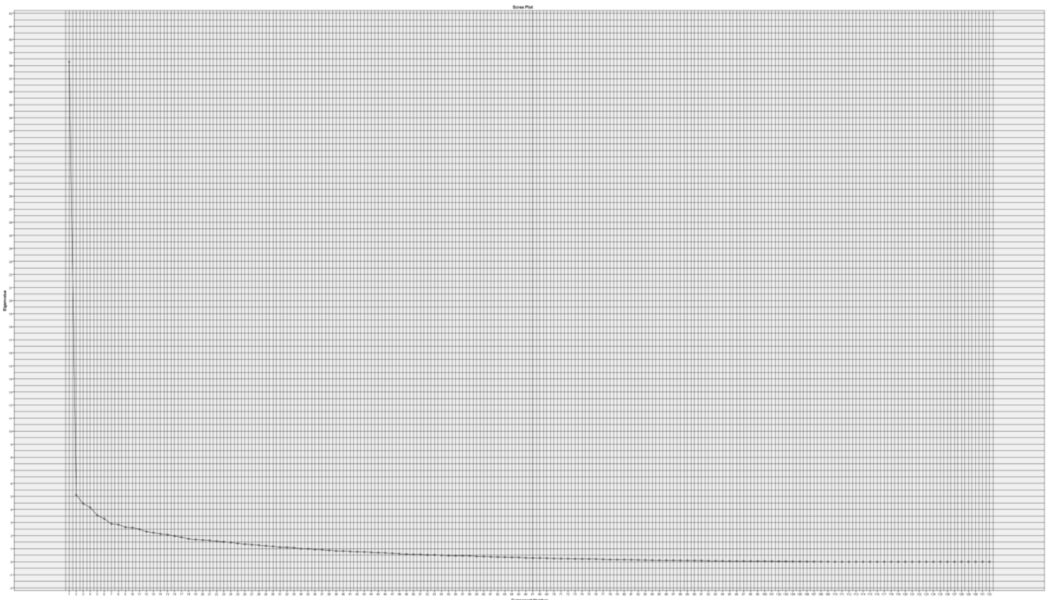


Figure 10:0:2: Scree Plot of 132 end user factor of the Study (the Grid)

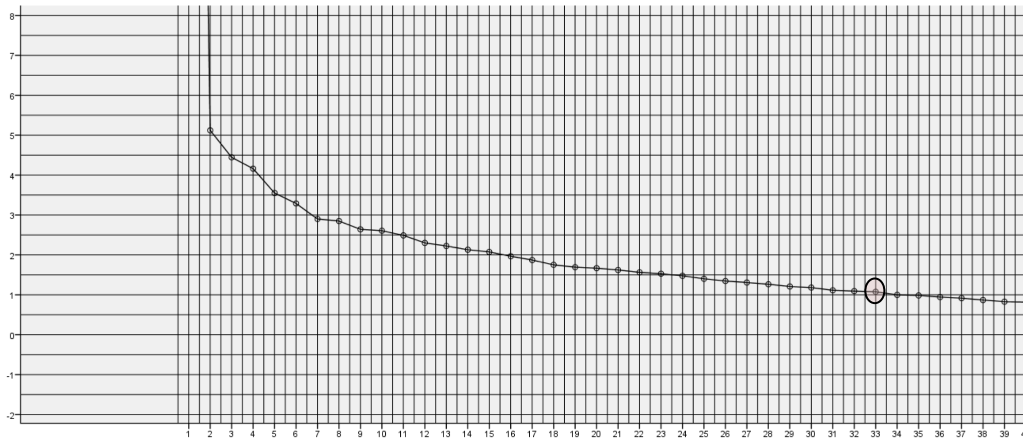


Figure 10:0:3: Scree Plot of 33 end user factor of the Study (the point 33 components more than 1)

Tables K-A, K-B and K-C in Appendix K present the level of effectiveness of each EUF in the whole survey. As is obvious, each component is correlated with all EUFs. As has been presented in Tables K-A, K-B and K-C in Appendix K, all components are correlated with all end user factors. The rotate component matrix used to highlight the most effective EUFs.

For instance, the most influential factor in the component is DB3, which carries a score of 0.281. Also, there is a close interval between DB2 and DB5. This shows the level of affiliation in this group. There is also another effective EUF in the same compenent, AE3, which is equal to .1 and BB3 which is equal to 0.117. In this way, the most effective EUFs, which are those with high scores and with correlation value too for each component, have been selected, as shown in Table 10-2, which shows the components based on rotated Table 10-1 component matrices presented.

Component: 1	Component: 2	Component: 3	Component: 4
DB2: Design passive building to adapt for dysfunctional future utilisation **DB3:** Allow ample floor-to-floor height for future modification **DB4:** Consider the passive design that accommodates fundamental changes in user preferences **DB5:** Design the passive space to cope with changes in flow of users	**AC2:** Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	**AE4:** Use Trombe wall or double façade to collect solar gain	**BE5:** Atrium or rotunda control devices for optimum space comfort
Component: 5	**Component: 6**	**Component: 7**	**Component: 8**
BB2: Select good colour to use	**AC11:** Narrow floor width to optimise natural ventilation	**BE4:** The lighting quality enhances or interferes with well-being of occupants	**AC8:** Consider interior surface colours and finishes for optimum day lighting **AC9:** Design plan to create buffer zones from the summer radiation **AC10:** Plan specific spaces or functions to coincide with solar orientation
Component: 9	**Component: 10**	**Component: 11**	**Component: 12**
BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants **BD1:** A comfortable internal air temperature	**FC3:** Access routes of passive space for transport of maintenance materials	**AA3:** Use nearby landforms and structures for wind protection and summer shading	**AB4:** Use high mass construction with appropriate insulation to promote night ventilation
Component: 13	**Component: 14**	**Component: 15**	**Component: 16**

AC8: Consider interior surface colours and finishes for optimum day lighting	**AC1:** Subdivide interior to create separate heating and cooling zones	**DA3:** Allow ample floor-to-floor height for future modification	**CA1:** Optimum position of service and passive element or equipment for operability
Component: 17	**Component: 18**	**Component: 19**	**Component: 20**
EA4: Select components that are resistant to environmental agents	**BC1:** The temperature controls provide for the needs of different occupants	**FA6:** Design for ease to remove or replace lighting, ventilation and thermal comfort elements **FA7:** Design for ease to adjust lighting, ventilation and thermal comfort physical element features	**AE6:** Minimise openings in envelope to reduce thermal gain
Component: 21	**Component: 22**	**Component: 23**	**Component: 24**
AE8: Develop details to minimise air infiltration and exfiltration	**FA2:** Simplify interface of passive design elements and building façade	**AB2:** Use low mass construction to allow rapid heat-up or cooling of structure	**FA2:** Simplify interface of passive design elements and building façade
Component: 25	**Component: 26**	**Component: 27**	**Component: 28**
EB4: Use standardisation of passive design elements and materials	**BE3:** The visual comfort of the lighting (e.g., glare, reflections, contrast)	**AB3:** Shape the building to maximise exposure to [winter sun and summer breezes]	**DA9:** Design passive space to respond to changes in climate conditions
Component: 29	**Component: 30**	**Component: 31**	**Component: 32**
BB6: Space layout enhances or interferes with well-being of occupants	**AE10:** Use louvred wall formaximum ventilation control	**EA2:** Provide optimum drainage and venting to minimise accumulation of moisture	**FC4:** Critical lighting, ventilation and thermal comfort element should be visible for inspection **FC5:** All elements of the external passive building shell should be easy to access for maintenance and cleaning **FC6:** Optimise sizes for passive design openings for workmanship access **FC7:** Locate passive design elements where they are accessible for maintenance and repair
Component: 33			
AD2: Use skylight, light tube and clerestory for natural illumination			

Table 10-2: Summarises the previous Tables K-A, K-B and K-C in Appendix K

The highest effective EUF has been selected. It has been clustered into 6 clusters, as shown in Table 10-3. Each cluster covered some EUFs based on Table 10-2. Each cluster is considered as UCPBD ATTs that can help the designer to assess their design, with regard to whether it involves EUFs or not. The variance percentage for each component has been extracted from Table 10-1. Then it has been grouped and their EUFs are provided in Table 10-2. The result of calculating the percentage variance for each cluster has been illustrated in Table 10-3. For example, ATT four presents PDFL. The calculation is done as follows: component (15) 1.571% + .957% for component (28) + component (1) 29.005 = 31.533%. This is the variance for cluster 4. This result is out of the total value 81.02%. As shown in Table 1, the summation of the percentage of 33 components is the same at 81.02%. This means these components can be representative of UCPBD. Using this method by SPSS program leads to reducing the EUFs down to 44 from 132. The 44 EUFs are grouped into 6 clusters, as shown in Figure 10:4. The remaining data is 18.98% out of 100%, which means the 6 clusters are highly manageable. This process has included clustering them into 6 clusters, components of each cluster, EUFs of each component, variance percentage for each component, and total variance percentage for each cluster, as shown in Table 10-3.

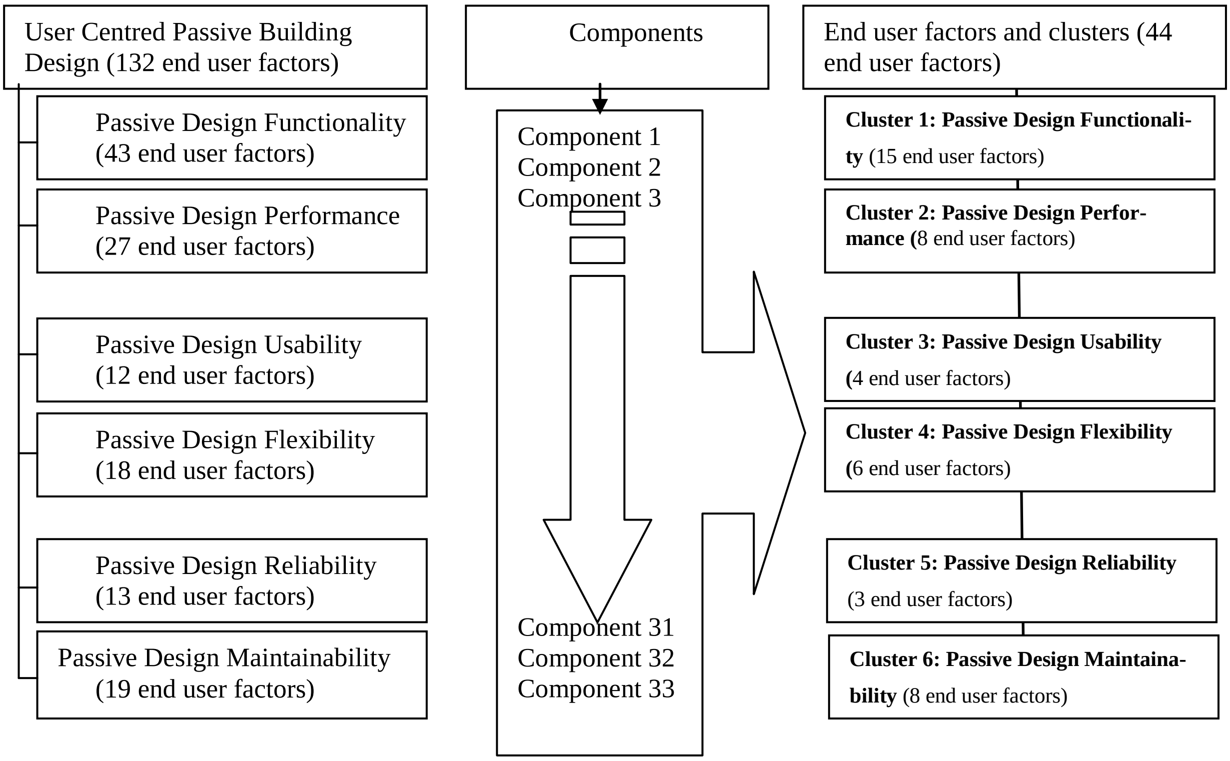


Figure 10:0:4: The process of data reduction and group analysis

Cluster 1: Passive design Functionality	**Cluster 2: Passive design Performance**	**Cluster 3: Passive design Usability**	**Cluster 4: Passive design Flexibility**	**Cluster 5: Passive design Reliability**	**Cluster 6: Passive design Maintainability**
Component :11 Component :23 Component: 27 Component: 12 Component :14 Component : 2 Component :13 Component :8 Component : 6 Component: 33 Component : 3 Component : 20 Component : 21 Component :30	Component :5 Component :29 Component : 18 Component :9 Component : 26 Component :7 Component : 4	Component: 16	Component :15 Component : 28 Component : 1	Component :31 Component : 1 Component : 25	Component :22 Component : 24 Component : 19 Component : 10 Component : 32
AA3: Use nearby landforms and structures for wind protection and summer shading **AB2:** Use low mass construction to allow rapid heat-up or cooling of structure **AB3:** Shape the building to maximise exposure to [winter sun and summer breezes] **AB4:** Use high mass construction with appropriate insulation to promote night ventilation **AC1:** Subdivide interior to create	**BB2:** Select good colour to use **BB6:** Space layout enhances or interferes with well-being of occupants **BC1:** The temperature controls provide for the needs of different occupants **BC2:** Thermal comfort in spaces enhances or interferes with well-being of occupants **BD1:** A comfortable internal air temperature **BE3:** The visual comfort of the lighting (e.g., glare, reflections,	**CA1:** Optimum position of service and passive element or equipment for operability **CA2:** Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas), **CA3:** Group homogeneous passive functions together for efficient operability **CA4:** Avoid slopes and steps of passive space floors	**DA3:** Allow ample floor-to-floor height for future modification **DA9:** Design passive space to respond to changes in climate conditions **DB2:** Design passive building to adapt for dysfunctional future utilisation **DB3:** Allow ample floor-to-floor height for future modification **DB4:** Consider the passive design that	**EA2:** Provide optimum drainage and venting to minimise accumulation of moisture **EA4:** Select components that are resistant to environmental agents **EB4:** Use standardisation of passive design elements and materials	**FA2:** Simplify interface of passive design elements and building façade **FA6:** Design for ease to remove or replace lighting, ventilation and thermal comfort elements **FA7:** Design for ease to adjust lighting, ventilation and thermal comfort physical element features **FC3:** Access routes of passive space for transport of maintenance materials **FC4:** Critical lighting, ventilation and thermal comfort

separate heating and cooling zones **AC2:** Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible **AC8:** Consider interior surface colours and finishes for optimum day lighting **AC9:** Design plan to create buffer zones from the summer radiation **AC10:** Plan specific spaces or functions to coincide with solar orientation **AC11:** Narrow floor width to optimise natural ventilation **AD2:** Use skylight, light tube and clerestory for natural illumination **AE4:** Use Trombe wall or double façade to collect solar gain **AE6:** Minimise openings in envelope to reduce thermal gain **AE8:** Develop details to minimise air infiltration and ex-filtration **AE10:** Use louvred wall for maximum ventilation control	contrast) **BE4:** The lighting quality enhances or interferes with well-being of occupants **BE5:** Atrium or rotunda control devices for optimum space comfort		accommodates fundamental changes in user preferences **DB5:** Design the passive space to cope with changes in flow of users		element should be visible for inspection **FC5:** All elements of the external passive building shell should be easy to access for maintenance and cleaning **FC6:** Optimise sizes for passive design openings for workmanship access **FC7:** Locate passive design elements where they are accessible for maintenance and repair
1.885	2.690	1.490	1.571	.843	1.184
1.158	.916		.957	1.417	1.118
.990	1.327		29.005	1.061	1.282
1.743	2.000				1.974
1.613	1.019				.828
3.880	2.197				
1.684	3.152				
2.157					
2.492					
.815					
3.367					
1.263					
1.228					
.895					
25.17	**13.301**	**1.49**	**31.533**	**3.321**	**6.386**

Table 10-3: Factor reduction of six clusters of end user centred passive building design.

The 6 clusters of user centred passive building design will be used for developing a tool that helps the designer to integrate EUFs.

10.6 Interpretation of each cluster

The name of each cluster has been selected in order to conduct the correlation between each EUF. The EUFs are grouped in order of their ATTs. The factors are grouped in a hierarchical order based on their code. The interpretation of each one will be discussed as follows.

10.6.1 Passive Design Functionality

The variance percentage of this cluster is 25.17 %. 15 EUFs are involved in the components of this cluster. The 15 EUFs are: AA3: Use nearby landforms and structures for wind protection and summer shading, AB2: Use low mass construction to allow rapid heat-up or cooling of structure, AB3: Shape the building to maximise exposure to [winter sun and summer breezes], AB4: Use high mass construction with appropriate insulation to promote night ventilation, AC1: Subdivide interior to create separate heating and cooling zones, AC2: Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible, AC8: Consider interior surface colours and finishes for optimum day lighting, AC9: Design plan to create buffer zones from the summer radiation, AC10: Plan specific spaces or functions to coincide with solar orientation, AC11: Narrow floor width to optimise natural ventilation, AD2: Use skylight, light tube and clerestory for natural illumination, AE4: Use Trombe wall or double façade to collect solar gain, AE6: Minimise openings in envelope to reduce thermal gain, AE8: Develop details to minimise air infiltration and ex-filtration and AE10: Use louvred wall for maximum ventilation control]. These EUFs are related to how PDF should be optimised for the end user. Providing these strategies means increasing the satisfaction of EUs and considering their needs in terms of design function at an early stage of the design. For this reason this cluster has been called PDF.

10.6.2 Passive Design Performance

This cluster has a variance percentage of 13.301%. It consists of 8 EUFs that are related to PDP namely: BB2: Select good colour to use, BB6: Space layout enhances or interferes with well-being of occupants, BC1: The temperature controls provide for the needs of different occupants, BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants, BD1: A comfortable internal air temperature, BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast), BE4: The lighting quality enhances or interferes with well-being of occupants and BE5: Atrium or rotunda control devices for optimum space comfort). It is obvious that all of them are related to design performance. Considering these EUFs in the early design stage means that high performance design functions will be delivered, in order to fulfil EU needs. Considering these EUFs reduces EU complaints and mitigates the risk and the mistakes before delivering the design. This will provide the optimum design in terms of lighting, ventilation and heating.

10.6.3 Passive Design Usability

Cluster 4 is related to PDU and its percentage of variance is 1.49%. It consists of four EUFs which are: CA1: Optimum position of service and passive element or equipment for operability, CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas), CA3: Group homogeneous passive functions together for efficient operability and CA4: Avoid slopes and steps of passive space floors. This end user factor can help the user to use and control the element easily. Applying this factor will lead to fulfilling user needs and optimising passive design lighting, ventilation and heating. These strategies can play a leading role in providing lighting and ventilation in a way that makes the space suitable for use. Its selection as one of the variance EUFs is expectable because it was selected based on the literature review.

10.6.4 Passive Design Flexibility

PDFL of UCPBD included six EUFs which are (DA3: Allow ample floor-to-floor height for future modification, DA9: Design passive space to respond to changes in climate conditions, DB2: Design passive building to adapt for dysfunctional future utilisation, DB3: Allow ample floor-to-floor height for future modification, DB4: Consider the passive design that accommodates fundamental changes in user preferences, DB5: Design the passive space to cope with changes in flow of users). The total variance of these factors is 31.533%. This percentage is the highest percentage in the hierarchy of the six groups. Using these strategies in the building means the design is optimum and flexible for EU in terms of environmental conditions and EU needs.

10.6.5 Passive Design Reliability

The variance percentage of this cluster is 3.321% in UCPBD. All of the EUFs are related to providing a reliable design for the occupant and EU. The three EUFs are: EA2: Provide optimum drainage and venting to minimise accumulation of moisture, EA4: Select components that are resistant to environmental agents and EB4: Use standardisation of passive design elements and materials. As has been stated, these are related to design reliability. These solutions can lead to satisfying EU needs and enabling PDS to be merged to deliver high reliability for PD. This can be considered in the early design stages and development design process.

10.6.6 Passive Design Maintainability

The last cluster includes 8 EUFs which are: FA2: Simplify interface of passive design elements and building façade, FA6: Design for ease to remove or replace lighting, ventilation and thermal comfort elements, FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features, FC3: Access routes of passive space for transport of maintenance materials, FC4: Critical lighting, ventilation and thermal comfort element should be visible for inspection, FC5: All elements of the external passive building shell should be easy to access for maintenance and cleaning, FC6: Optimise sizes for passive design openings for workmanship access and FC7: Locate PD elements where they are accessible for maintenance and repair. The total variance of this ATT is 6.386%. The various aspects can play a vital role in the PDM. Applying these strategies can lead to optimise the design in terms of maintainability; and can also lead to reduce user complaints and provide a design that is able to cope with their needs at the current time and in the future.

10.7 Reliability Testing

As introduced in the previous chapters, reliability testing can be used for checking the possibility of grouping the EUFs together. Cronbach's alpha is used to check if the group result is more than 5, which means that it is reliable, and in case it is less than 5, this means it is an unreliable group. Reliability analysis is used to analyse the six cluster ATTs to test the possibility of grouping the EUFs into S-ATTs. This analysis is done by computing Cronbach's alpha, as shown in Table 10-4, where 6 cluster ATTs are more than 0.50; for this reason they are considered to be more reliable.

The grouping cluster	**The end user factors**	**Cronbach's Alpha for the whole Attribute**
Passive Design Functionality (PDF)	**AA3:** Use nearby landforms and structures for wind protection and summer shading	.784
	AB2: Use low mass construction to allow rapid heat-up or cooling of structure	
	AB3: Shape the building to maximise exposure to [winter sun and summer breezes]	
	AB4: Use high mass construction with appropriate insulation to promote night ventilation	
	AC1: Subdivide interior to create separate heating and cooling zones	
	AC2: Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	
	AC8: Consider interior surface colours and finishes for optimum day lighting	
	AC9: Design plan to create buffer zones from the summer radiation	
	AC10: Plan specific spaces or functions to coincide with solar orientation	
	AC11: Narrow floor width to optimise natural ventilation	
	AD2: Use skylight, light tube and clerestory for natural illumination	
	AE4: Use Trombe wall or double façade to collect solar gain	
	AE6: Minimise openings in envelope to reduce thermal gain	
	AE8: Develop details to minimise air infiltration and ex-filtration	
	AE10: Use louvred wall for maximum ventilation control	
Passive Design Performance (PDP)	**BB2:** Select good colour to use	.751
	BB6: Space layout enhances or interferes with well-being of occupants	
	BC1: The temperature controls provide for the needs of different occupants	
	BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants	
	BD1: A comfortable internal air temperature	
	BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast)	
	BE4: The lighting quality enhances or interferes with well-being of occupants	
	BE5: Atrium or rotunda control devices for optimum space comfort	
Passive Design Usability (PDU)	**CA1:** Optimum position of service and passive element or equipment for operability	.698
	CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	
	CA3: Group homogeneous passive functions together for efficient operability	
	CA4: Avoid slopes and steps of passive space floors	
Passive design Flexibility (PDFL)	**DA3:** Allow ample floor-to-floor height for future modification	.806
	DA9: Design passive space to respond to changes in climate conditions	
	DB2: Design passive building to adapt for dysfunctional future utilisation	
	DB3: Flexible access within and between passive spaces	
	DB4: Consider the passive design that accommodates fundamental changes in user preferences	
	DB5: Design the passive space to cope with changes in flow of users	
Passive design Reliability (PDR)	**EA2:** Provide optimum drainage and venting to minimise accumulation of moisture	.539
	EA4: Select components that are resistant to environmental agents	
	EB4: Use standardisation of passive design elements and materials	
Passive Design Maintainability (PDM)	**FA2:** Simplify interface of passive design elements and building façade	.867
	FA6: Design for ease to remove or replace lighting, ventilation and thermal comfort elements	
	FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features	

	FC3: Access routes of passive space for transport of maintenance materials	
	FC4: Critical lighting, ventilation and thermal comfort element should be visible for inspection	
	FC5: All elements of the external passive building shell should be easy to access for maintenance and cleaning	
	FC6: Optimise sizes for passive design openings for workmanship access	
	FC7: Locate passive design elements where they are accessible for maintenance and repair	

Table 10-4: Testing the reliability of the six clusters

10.8 The Result Implication:

This section discusses the statistical result implication on some of the conceptual model components. It is important to point out that the main objective of the statistical analysis is to check out the importance of the selected EU attributes. The initial set of attributes is too extensive to use any subsequent method for assessing the integration of EUFs into passive design strategies. Thus the main implication will be in the reduction of attributes. For example, the Passive Deign Functionality component of the model consisted initially of 43 end user factors, through the factor analysis this number is reduced to 15 as shown in the figure 10:4. Similarly for Passive Deign Performance component reduced from 27 to 8 end user factors. Likewise Passive Deign Usability factors are reduced to 4 from 12 end user factors. Passive Design Flexibility factors were grouped into 6 factors insisted of 18. Passive Design Reliability complement consisted now from only 3 end-user factors instead of 13. Passive Design Maintainability is represented by 8 end user factors instead of 19. The selected clusters are shown in Fig 10.4. Although the number of EUs factors are reduced from 132 to 44 only 19% of information is lost. That is to say the selected clusters represent 81.20 of the captured information from the survey. Thus, one might argue that the impact on the information than can be generated from conceptual model is minimal. But the usability of the conceptual model is increased through the ease of use.

10.9 Summary of this Chapter

The EUFs were reduced to 44 from an initial total of 132 by using SPSS. The 44 EUFs were then clustered into 6 groups as follows:

Cluster 1: Passive Design Functionality (25.17% variance percentage)

Cluster 2: Passive Design Performance (13.301% variance percentage)

Cluster 3: Passive Design Usability (1.49% variance percentage)

Cluster 4: Passive Design Flexibility (31.533% variance percentage)

Cluster 5: Passive Design Reliability (3.321% variance percentage)

Cluster 6: Passive Design Maintainability (6.386% variance percentage)

This classification of UCPBD has been introduced based on UCPBD ATTs. In this research, EU needs have been merged with PDS to be an aim that the designer needs to meet. Other research concentrates searching for environmental issues more than fulfilling EU needs, especially during the design process.

Chapter Eleven: UCPBD Assessment Tool

11.1 Introduction:

It is important to develop the conceptual model to be an assessment tool to evaluate PBD, to see whether or not it meets EU needs. For this reason, adapting the methodology of an existing tool can help the researcher to think about proposing a new tool. Design quality indicators, BREEAM, LEED and other methods are used to assess the design and building, to see if it is sustainable or not. Each one of these methods is classified into several groups and each group has several indicators. This is similar to the structure of our conceptual tool. Each one of them includes rate and scores for assessment. In the following section, the assessment tool will be reviewed and some of its ratings and equations will be adapted if available, as follows:

11.2 Review the existing assessment tool

There are various assessment tools that have been applied and used in different countries. The main aim of these tools is to enhance building sustainability. One of the main issues is to consider the ecological and environmental issues. The various assessment tools include BREEAM, LEED, DGNB Labe, GREEN STAR, and CASBEE. Each one of these includes various indicators and groups. Dirlich (2011) referred to these tools and made comparisons between them, which are introduced in the following section:

11.2.1 Comparisons

The criteria of assessment tools are similar to each other, as referred to by Dirlich (2011). He indicated that these tools consider several criteria such as site, outdoor and indoor environment, water, material, land use and transport, health and well-being, and pollution. Each one of them includes several criteria and sub-criteria. These criteria will be assessed during the assessment process and a score will be given to each one. These criteria have been integrated into the UCPBD tool. The first trend is ecological, which is represented in PDS and the second trend is EU needs, which is not considered in the assessment tool criteria. In addition to that, the certification of each assessment tool is different. The criteria of this study's proposed assessment tool is different than the criteria of these assessment tools, especially as this research considered different issues in detail, such as flexibility, usability, reliability and maintainability. These criteria and their S-ATTs with their EUFs are considered in order to meet EU needs as well as the environmental issues. This is a clear difference between these criteria and the UCPBD criteria.

The certification is different between these tools, some of them using good and very good scales and other using silver and gold scale. However, CASBEE is different than other tools. CASBEE includes two assessment categories, which are the building's environmental quality and performance and the reduction of environmental loads of the building, as referred to by Dirlich (2011). These two categories are divided by each other to get the result. The German tool can be classified as a comprehensive tool; it comprises economic, social-cultural, technical, functional, and building quality plus ecological aspects. The existing assessment tools' categories have been listed. The differences between the categories are insignificant, as Dirlich (2011) claimed. He classified the categories as shown in the following Table (11-1).

Criterion	BREEAM	CASBEE	GREEN STAR	LEED	DGNB Label
Management	+	-	+	-	+
Sustainable Sites	-	-		+	+
Indoor Environmental Quality		+	+	+	+
Quality of services	-	+	-	-	+
Outdoor Environment	-	+	-	-	+
Energy	+	+	+	+	+
Materials	+	-	+	-	+
Resources and material	-	+	-	+	+
Off site Environment	-	+	-	-	+
Transport	+	-	+	-	+
Water	+	-	+	+	+
Land use and ecology	+	-	+	-	+
Emissions and ecology	+	-	+	+	+
Innovation	-	-	+	+	-
Health and well-being	+	-	-	-	+

Table 11-1: Summary of considered categories (Dirlich, 2011)

The plus marks cells on the table are for the criteria that are considered in each tool. Three tools are considered: the management by German DGNB Label, Green Star and BREEAM. Health and well-being are considered by BREEAM and German DGNB Label. The list factors of both tools are shown in the table below (11-2):

Criterion	BREEAM(Health and well-being)	DGNB Label(Socio-cultural and Functional Quality)
Daylighting	+	+
Indoor air quality	+	-
Thermal comfort	+	+
Water quality and	+	-
Acoustic performance	+	+
Safety and security	+	+
Indoor Hygiene	-	+
Influences by Users	-	+
Roof Design	-	+
Barrier free Accessibility	-	+
Area Efficiency	-	+
Feasibility of Conversion	-	+
Accessibility	-	+
Bicycle Comfort	-	+
Assurance of the Quality of the Design and for Urban Development for Competition	-	+
Art within Architecture	-	+

Table 11-2: Summary of comparison between BREEAM (Health and well-being) and DGNB Label (Socio-cultural and Functional Quality): (-) = the criterion is not involved. (+) the criterion is involved

Dirlich (2011) claimed that these tools considered EU needs under health and well-being. The criteria in Table 11-2 have been met in this study's UCPBD tool. However, the main ATTs and S-ATTs and EUFs were classified in such a way for all of them to meet EU needs without specifying special

ATTs. The researcher looked to the EU needs from six perspectives: functionality, performance, usability, flexibility, reliability and maintainability.

The similarities of assessment tools are clear with simple differences in the criteria. However, CASBEE is different as its score system is relying on points. In addition to that, CASBEE considers geographical issues as well as regional ATTs. As an assessment tool, the German DGNB Label differs from other tools due to its holistic and flexible approach. Also, its way of weighting and calculation is different than other tools. The calculation depends on their local green building. Each assessment tool has its advantages and disadvantages. The challenge here is to provide a tool that can be flexible to adopt in any building, as, for example, the DGNB Label tool: its flexibility means that it can be easily adopted into any building. The majority of these criteria are as illustrated in Table 11-1. The listed criteria are dealing with ecological issues, functionality and performance. However, on the one hand, the UCPBD conceptual model is dealing with six attributes, which are functionality, performance, usability, flexibility, reliability and maintainability. On the other hand, the UCPBD conceptual model considers EU needs at the same time as ecological issues. UCPBD attributes do not have matches in any assessment tool; this has been assessed based on comparisons with the following assessment tools: BREEAM, CASBEE, Green star, LEED, FGNB Label, EU Ecolabel for new buildings, Code for Sustainable Homes, LEnSE, SBTool and TQB Criteria, as shown in Table 11-3. These tools are looking to the ecological and environmental issues more than to the user. They pay attention to the EU but it is not their main concern. UCPBD has developed and selected its EUFs in order to fulfil EU needs; this is the difference between it and the rest of the tools. The attributes of the tool are selected in order to to fulfil EU needs in different trends.

Existing assessment Criterion	UCPBD attributes					
	Functionality	**Performance**	**Usability**	**Flexibility**	**Reliability**	**Maintainability**
BREEAM	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these attributes'		There are no main criteria that cover the issue of usability	There are no main criteria that cover the issue of flexibility	The material is referred to as a main criterion; however it covers all reliability issues	There are no criteria that cover the issue of usability
CASBEE	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these attributes'		There are no main criteria that cover the issue of usability	There are no main criteria that cover the issue of flexibility	There are no main criteria that cover the issue of reliability; however the material is referred to as a main criterion	There are no main criteria that cover the issue of maintainability. The material is referred to as a main criterion.
GREEN STAR	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these attributes'		There are no main criteria that cover the issue of usability	There are no main criteria that covered the issue of flexibility	There are no main criteria that cover the issue of reliability	There are no main criteria that cover the issue of maintainability
LEED	The majority of criteria are related to the functionality and performance; however no criteria named and classified as this research classified these attributes		There are no criteria that cover the issue of usability	There are no criteria that covered the issue of flexibility	Durability has been considered as a sub-attribute under innovation and design process	There are no main criteria that cover the issue of maintainability
DGNB Label	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these		There are no main criteria that cover the issue of usability	There are no main criteria that cover the issue of flexibility	There are no main criteria that cover the issue of reliability	It has referred to the issue of maintenance under technical

	attributes’				quality as well as accessibility under social/cultural issues
EU Ecolabel for new buildings	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these attributes’	There are no criteria that cover the issue of usability; however they paid attention to providing facilities	There are no main criteria that cover the issue of flexibility	There are no criteria that cover the issue of reliability; however they paid attention to material as the main criterion	There are criteria for maintenance and operation; they are limited on walls as well as cables
Code for Sustainable Homes	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these attributes’	There are no criteria that covered the issue of usability; however they paid attention to providing facilities	There are no main criteria that cover the issue of flexibility	There are no criteria that cover the issue of reliability; however they paid attention to material as the main criterion	There are no main criteria that cover the issue of maintainability
LEnSE	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these attributes’	There are no main criteria that covered the issue of usability	There are no main criteria that cover the issue of flexibility	There is no main criteria that covered the issue of reliability	It has referred to the accessibility under social criteria
SBTool	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these attributes’	There are no main criteria that covered the issue of usability	Under service quality referrred to Flexibility and Adaptability	There are no main criteria that cover the issue of reliability	Under service quality referred to maintenance of core building functions during power outages as well as Maintenance of Operating Performance
TQB Criteria	The majority of criteria are related to the functionality and performance; however no criteria have been named and classified as this research has classified these attributes’	There are no main criteria that cover the issue of usability	There are no main criteria that cover the issue of flexibility	Under Economic and Technical Performance referred to Durability and Adaptability	There are no main criteria that cover the issue of maintainability

Table 11-3: Summary of comparison between BREEAM (BREEAM, 2011), CASBEE (Chung, 2005), Green star (URS, 2006), LEED, FGNB Label, EU Ecolabel for new buildings, Code for Sustainable Homes, LEnSE, SBTool, TQB Criteria (Mötzl and Fellner, 2011) and the attributes of this study’s UCPBD tool

BREEAM as an assessment tool is also made up of several clusters with different indicators. The reason this research considered this assessment tool was in order to investigate the method of weightings. Inbuilt (2010) introduced BREEAM 2008, which was developed based on BREEAM 2006. They stated that the BREEAM 2008 includes a new rating, which is the “outstanding” one, as shown in Table 11-4. As it is introduced, the score is a percentage, which is the later stage after the point scores. However, LEED keeps the weighting points, as shown in Table 11-5.

BREEAM rating	% score
Unclassified	<30
Pass	≥30
Good	≥45
Very Good	≥55
Excellent	≥70
Outstanding	≥85

Table 11-4: BREEAM rating (Inbuilt, 2010)

LEED rating	Points
Certified	40-49
Silver	50-59
Gold	60-79
Platinum	80 points and above

Table 11-5: LEED Rating (Inbuilt, 2010)

Based on their tools and way of weighting and classification, the researcher can adapt the rate to assess each level of the PD based on the points and percentages, as will be introduced in the following sections. The UCPBD is distinguished by its consideration of various design ATTs to fulfil both EU needs and ecological issues. However, there is another tool, which is called design quality indicators. This tool refers to one of UCPBD's ATTs, which is functionality, as well as environmental impact and building quality. The functionality ATT is the main concern that matches the PDF. For this reason, it could be reviewed as a method, as will be shown in the following section.

11.2.2 Design quality indicators

The design quality indicator is a tool that was developed to assess the design quality. Egan (2002, as cited in Gann et al, 2003) said that this tool was developed specifically for measuring the design quality. Although the tool was not planned to measure the design process, it is used at different stages of the design. This can help the designer to make a decision during the process. Gann et al (2003) said that the DQI development is based on the existing methods such as Post-occupancy Evaluation, BREEAM, LEED, CASBEE, GREEN STAR, DGNB Label and Housing Quality Indicators. These tools can be classified as the starting points to achieve this tool.

11.2.2.1 The conceptual framework

Furthermore, the conceptual framework of DQI is concentrated on the three main aspects, which are functionality, impact and building quality, and each one includes several criteria which are: use, access and space; performance, engineering systems and construction; and form and materials, internal environment, urban and social integration, identity and character (Gann et al, 2003). This shows the similarity with the structure of the tool, which includes criteria and sub-criteria which are the main cluster and the EUFs in this study's model.

11.2.2.2 Data Tool

It is important to use the data to develop a questionnaire that can be used by stakeholders who participate in the design process. The structure of the questionnaire is based on the division of the framework into three main aspects, criteria and sub-criteria respectively, as shown in Figure 11:1. The hierarchy of the questionnaire also matches the structure of the UCPBD ATTs, subs-ATTs and EUFs.

Build Quality

For sections **N** to **P** please additionally circle the 3 statements within each section that you feel are the most important for your building

N PERFORMANCE	Strongly Disagree	Disagree	Tend to Disagree	Tend to Agree	Agree	Strongly Agree	Not Applicable
01 The building is easy to clean	O	O	O	O	O	O	O
02 The building withstands wear and tear in use	O	O	O	O	O	O	O
03 The building is easily maintained	O	O	O	O	O	O	O
04 The building design has responded to the site microclimate	O	O	O	O	O	O	O
05 The building will weather well	O	O	O	O	O	O	O
06 The building's structure is efficient	O	O	O	O	O	O	O
07 The building's finishes are durable	O	O	O	O	O	O	O
08 There is sufficient daylight in the building	O	O	O	O	O	O	O
09 The artificial lighting levels in the building are sufficient	O	O	O	O	O	O	O
10 The thermal climate in the building is appropriate to its use	O	O	O	O	O	O	O
11 The acoustics quality is appropriate to its use	O	O	O	O	O	O	O
12 The air quality is appropriate to its use	O	O	O	O	O	O	O
13 The building is easy to operate	O	O	O	O	O	O	O
14 The building produces a low number of complaints/faults reported by users	O	O	O	O	O	O	O

Figure 11:1: The details of section of DQI (Gann et al, 2003)

11.2.2.3 The weighting mechanism

Gann et al (2003) have referred to the weighting mechanism that has been used in analysing the data of the questionnaire. The respondents were asked to give scores for each statement, and then they were asked to circle the most important of the three statements in each section. At the end, they asked the respondents to rank the most important aspect, and then compare it with their weighting of each sub-section. The weighting mechanisms that have been used are DQI = (FU + I +BQ)/X.

FU = Functionality

I = Impact

BQ = Building Quality

X = is assumed to be the total of indicators' scores.

Based on the techniques of this equation, an equation can be developed and created that will help the designer to calculate the level of meeting EU needs during the design process.

11.3 Developing a User Centred passive building design assessment tool

UCPBD as a tool has been developed based on a critical literature review and a critical refinement of the EUFs. The refinement was extracted as shown in Chapter 10. The EUFs have been identified and highlighted in each component as shown in the components table. The extracted EUFs have been listed and grouped into 6 clusters. These clusters include several EUFs which are grouped based on their relation to each other. This assessment tool will include a scoring system, selected EUFs, weighting of the EUFs based on component, computing of the scoring, plotting the result, the case study, implication and discussion.

11.3.1 Scoring system

The scoring system of this tool has been developed based on both BREEAM and LEED, and the scale has been developed based on Vakili-Ardebili (2004). The latter developed an assessment tool for Eco building Design. The indicators of his tool were delivered to several case studies to ask the designers of these projects to score it from 0 not implemented to 10 high implementation. The same method has been adopted in this study, as shown in the UCPBD sheet.

11.3.2 Selection factor

Selection of EUFs has been referred to in the introduction of the UCPBD tool. It has been extracted based on the component findings, as shown in Chapter 10. This was made through using analysis of EUFs as well as the redundant data. The redundant data was the method to reduce the number of EUFs. There were 33 remaining components. Then the EUFs were correlated with the components to identify the highest effective EUFs, as highlighted in red in Appendix K.

11.3.3 Weighting of the factors based on components

The value of each EUF has been identified through the correlation between the components and EUFs. Then, it has been listed in an ascending order, as shown in Table 11-6.

Cluster 1: Passive design Functionality (PDFL)	**Cluster 2: Passive design Performance (PDP)**	**Cluster 3: Passive design Usability (PDU)**	**Cluster 4: Passive design Flexibility (PDF)**	**Cluster 5: Passive design Reliability (PDR)**	**Cluster 6: Passive design Maintainability (PDM)**
AA3: AB2: AB3: AB4: AC1: AC2: AC8: AC9: AC10: AC11: AD2: AE4: AE6: AE8: AE10:	**BB2: BB6: BC1: BC2: BD1: BE3: BE4: BE5:**	**CA1: CA2: CA3: CA4:**	**DA3: DA9: DB2: DB3: DB4: DB5:**	**EA2: EA4: EB4:**	**FA2: FA6 FA7: FC3: FC4: FC5: FC6: FC7:**
.114	.322	.239	.115	.204	.239
.316	.133	.024	.225	.321	.263
.122	.286	.028	.230	.260	.253
.336	.300	.032	.281		.090
.380	.175		.142		.292
.111	.284		.118		.217
.103	.216				.165
.185	.378				.177
.301					
.303					
.083					
.273					
.305					
.346					
.334					
3.612	2.094	.323	1.111	0.785	0.177

Table 11-6: The component weight for each end user factor of the UCPBD tool

The weighting of these EUFs has been considered by multiplying them with the designers' scores in each case study, based on their hierarchy level. The researcher referred to the weighting of these results by W and for their scores by F.S. factor as shown in Table 11-6.

11.3.4 Computing of the scoring

The computing of this tool has been developed based on four steps as follows:
It was necessary to find a method that could help the researcher to score each factor separately. For this reason F.S. has been identified. F.S. (Factor scores) = the score of each EUF. This score has been identified based on the architect score for each case study. The value has been extracted from correlation between EUFs and the components. The value of each EUF has been given a symbol (Ws), as shown in the total score equation. Then F.S. has been multiplied by Ws for each EUF before all of them were summed together, as shown in the weighted mean score equation. Then this has been divided by total weight and multiplied by 10, which is the highest score for each EUF. Then, the result will be multiplied by 100 to get the percentage of the result. This equation is called $\mathrm{W_{ms}}$. Based on these equations, the weight of each cluster can be identified. How these equations are going to be implemented will be shown in the following section.

Total score equation (T_s) = $\sum_{i=1}^{i=n} F.S_s * W_s$

$$W_{ms} = \frac{Ts}{\sum_{i=1}^{n} w * 10}$$

W_{ms} = weighted mean score

Percentage score $= W_{ms} \times 100$

11.3.5 Plotting the result

Mean equation was the starting point for finding the result of the model. The score of each factor has been multiplied, which has been identified based on the designers' given scores, with the weight of each EUF. Then each cluster has been summed, as highlighted by the red line, before multiplying it with the sum of the weight, which is highlighted by the blue colour. The result of the C.Mean is highlighted in green, as is illustrated in the last table for each case study.

11.4 The case studies

There are various case studies that can be used to test this tool. For this reason, this research has selected four to look at in detail; each of them considers environmental issues. Also, they are classified under sustainable and ecological projects. For this reason, the tool has been delivered to the architects who designed these buildings, so that they could give a score for each EUF, in order to see whether they considered or implemented them. And, if some have been implemented, to what level they have been implemented. To calculate their scores, this research has adapted the equation of design quality indicators, identifying the classification similar to BREEAM and LEED. In terms of the equation, each cluster was given a code, as follows: PDFU+ PDP+ PDU + PDF + PDR+ PDM. This is important to be take part in the equation. Another, the contents of the equation are 440 = the total number of the factors. The equation is shown in the following paragraph.

UCPBD tool = ∑ (PDFU+ PDP+ PDU + PDF + PDR+ PDM)/440 * 100. How can this equation be used? The indicators of each cluster should be calculated separately. Then, the total of all clusters should be summed together and divided by 440, the total number of EUFs. Then, the result has to be multiplied by 100 to achieve the scores, as shown in Table 11-7, which is adapted based on both BREEAM and LEED rate weight. The second part of the weight is to show the result of the equation with weight. The scores of the factors of each cluster should be calculated one by one through multiply them with the weight that has been identified through the correlation analysis. Then, the total of all clusters should be summed together and divided by 96.21, the total number of EUFs. Then, the result has to be multiplied by 100 to achieve the scores, as shown in Table 11-7 (score with weight).

UCPBD Rate	Score without weight		Score without weight	
	Points	Percentage	Points	Percentage
Unsatisfactory	0-175	<40	0-38.47	<40%
Satisfactory	176-219	≥40%	38.48- 48.10	≥40%
Moderate	220 - 263	≥50%	48.11–57.72	≥50%
Significant	264-307	≥60%	57.73-67.33	≥60%
High significant	308-440	≥70%	67.34-96.21	≥70%

Table 11-7: UCPBD rating

This can be used to calculate the points for each end user factor and then to see the rank of each cluster before achieving the total points of the design. Then the designer will find out to what extent the design matches EU needs within a passive building. The case studies will be shown in the following sections. The information for each project has been provided by Al-Rekabi (2012). She sent information about the following three projects.

11.4.1 Houghton Street Project

Houghton Street Project is an affordable housing project. It is a mix of various sizes: 2 bed bungalows and 2 bed, 3 bed and 4 bed houses. This project also comprises car parking, visitor parking, back garden and flower area, P.V. panels and harvesting of rain water. This project includes various aspects that consider the environmental issues, as follows:

- Maximisation of environmental products and technologies

This project is distinguished by several achievements such as designed to “code for sustainable homes level 4”, designed to “lifetime homes standards”, such as reducing the need for modification in the future, considering green spaces and providing a handbook for the tenants to advise them about the role to enhance achievement of sustainable aims. Reducing environmental impact has been achieved through various aspects, as follows:

- Reduce energy demand

To achieve this aim, various measures have been taken in this project: High level of insulation in the roof, floor and walls, double-glazed windows and doors including super low-e glass. Using natural material and and using timber frame for walls, floor and roof as well as considering using high standard of air tightness to minimise air leakage. Also, in this project heating and hot water have been supplied by using high efficiency gas-fired boilers. This project also included consideration of the sloped P.V roof to be suitable for installation of P.V panels; providing good lighting for all projects through increasing the size of the windows; providing sun-tunnels for day lighting; and selecting lights that consume low energy by incorporating a sensor.

- Reduce water demand

This target has been achieved through using low water in WCs, shallow water capacity in baths, providing spray taps in in the washbasins, installing a low flow shower, and reusing rain water for the garden and for toilet flushing.

- Reduce waste

To reduce the waste, some strategies were considered by the designer, such as external walls and openings were designed with a full brick dimension, which leads to reducing the costs. In addition, the brick is durable and high strength. Other strategies that were used include minimising the components such as doors and windows and maximising prefabrication off site, using recycled rainwater goods, management of site waste by the contractor, and minimising paper usage by using electronic files.

- Use of sustainable material

This is achieved by using natural material and A+ rated material, using high performance softwood for doors and windows, and using sustainable FSC accredited timber for the roof and upper floor: using material that does not need maintenance and is more durable.

- Landscaping

Considering green areas and using a green boundary instead of a brick wall and enhancing the visual aspect for the user through providing good views.

- Early involvement of the local community; and design to maximise neighbourhood interaction

The project involved the local residents in order to satisfy their needs; and also invited the local schoolchildren to design an eco house. Community engagement enhanced the design team. The bungalow housing also was designed to suit user needs.

Figure 11:2: Houghton Street Project (Denovodesign, 2012)

Houghton Street Project

Office Name	Denovo Design Ltd
Architect Name	Frank olkwski, Arwa Al-Rekabi
Project Location	Widnes

Scoring

Implantation or consideration of factors in Design

0 ← 5 → 10

Not implemented ← Considered → Highly Implemented

Case study : **Houghton Street**

	To what extents the following factors are implemented and considered in this design?	.S	T.P	D.P	W_s	Mean	W_{ms}
Passive Design Function-ality (PDF)	**AA3:** Use nearby landforms and structures for wind protection and summer shading	0	42	.28	.114	0	0.26
	AB2: Use low mass construction to allow rapid heat-up or cooling of structure	0			.316	0	
	AB3: Shape the building to maximise exposure to [winter sun and summer breezes]	0			.122	0	
	AB4: Use high mass construction with appropriate insulation to promote night ventilation	2			.336	0.67	
	AC1: Subdivide interior to create separate heating and cooling zones	9			.380	3.42	
	AC2: Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	0			.111	0	
	AC8: Consider interior surface colours and finishes for optimum day lighting	10			.103	1.03	
	AC9: Design plan to create buffer zones from the summer radiation	0			.185	0	
	AC10: Plan specific spaces or functions to coincide with solar orientation	8			.301	2.41	
	AC11: Narrow floor width to optimise natural ventilation	0			.303	0	
	AD2: Use skylight, light tube and clerestory for natural illumination	10			.083	0.83	
	AE4: Use Trombe wall or double façade to collect solar gain	0			.273	0	
	AE6: Minimise openings in envelope to reduce thermal gain	0			.305	0	
	AE8: Develop details to minimise air infiltration and ex-filtration	3			.346	1.04	
	AE10: Use louvred wall for maximum ventilation control	0			.334	0	
Passive Design Perfor-mance (PDP)	**BB2:** Select good colour to use	8	54	.68	.322	2.58	0.45
	BB6: Space layout enhances or interferes with well-being of occupants	9			.133	1.2	
	BC1: The temperature controls provide for the needs of different occupants	7			.286	2.00	
	BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants	10			.300	3	
	BD1: A comfortable internal air temperature	10			.175	1.75	
	BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast)	0			.284	0	
	BE4: The lighting quality enhances or interferes with well-being of occupants	10			.216	2.16	
	BE5: Atrium or rotunda control devices for optimum space comfort	0			.378	0	
Passive Design Usability (PDU)	**CA1:** Optimum position of service and passive element or equipment for operability	9	33	.83	.239	2.15	0.87
	CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	8			.024	0.19	
	CA3: Group homogeneous passive functions together for efficient operability	9			.028	0.25	
	CA4: Avoid slopes and steps of passive space floors	7			.032	0.22	
Passive design Flexibility (PDFL)	**DA3:** Allow ample floor-to-floor height for future modification	0	32	.53	.115	0	0.66
	DA9: Design passive space to respond to changes in climate conditions	8			.225	1.8	
	DB2: Design passive building to adapt for dysfunctional future utilisation	8			.230	1.84	
	DB3: Flexible access within and between passive spaces	10			.281	2.81	
	DB4: Consider the passive design that accommodates fundamental changes in user prefer-ences	6			.142	0.85	
	DB5: Design the passive space to cope with changes in flow of users	0			.118	0	
Passive design Reliability (PDR)	**EA2:** Provide optimum drainage and venting to minimise accumulation of moisture	8	22	.73	.204	1.63	0.72
	EA4: Select components that are resistant to environmental agents	6			.321	1.93	
	EB4: Use standardisation of passive design elements and materials	8			.260	2.08	
Passive Design Maintaina-bility (PDM)	**FA2:** Simplify interface of passive design elements and building façade	0	41	.51	.239	0	0.57
	FA6: Design for ease to remove or replace lighting, ventilation and thermal comfort elements	8			.263	2.10	
	FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features	8			.253	2.02	
	FC3: Access routes of passive space for transport of maintenance materials	0			.090	0	
	FC4: Critical lighting, ventilation and thermal comfort element should be visible for inspec-tion	8			.292	2.34	
	FC5: All elements of the external passive building shell should be easy to access for mainte-nance and cleaning	6			.217	1.30	
	FC6: Optimise sizes for passive design openings for workmanship access	5			.165	0.83	
	FC7: Locate passive design elements where they are accessible for maintenance and repair	6			.177	1.06	

Result without weight	UCPBD tool = $\frac{\sum PDF+PDP+PDU+PDFL+PDR+PDM}{440} * 100$	UCPBD tool = $\frac{\sum 42+54+33+32+22+41}{440} = \frac{224}{440} * 100$
	The Result = 50.91%	UCPBD Rate = Moderate
Result with weight	C.Mean= $\frac{Meqan\ Equation}{\sum W_s\ of\ each\ culster*10} * 100$	C.Mean = $\frac{9.4+12.69+2.81+7.3+5.64+9.65}{96.21} = \frac{47.49}{96.21} * 100$
	The Result = 49.36%	UCPBD Rate = Satisfactory

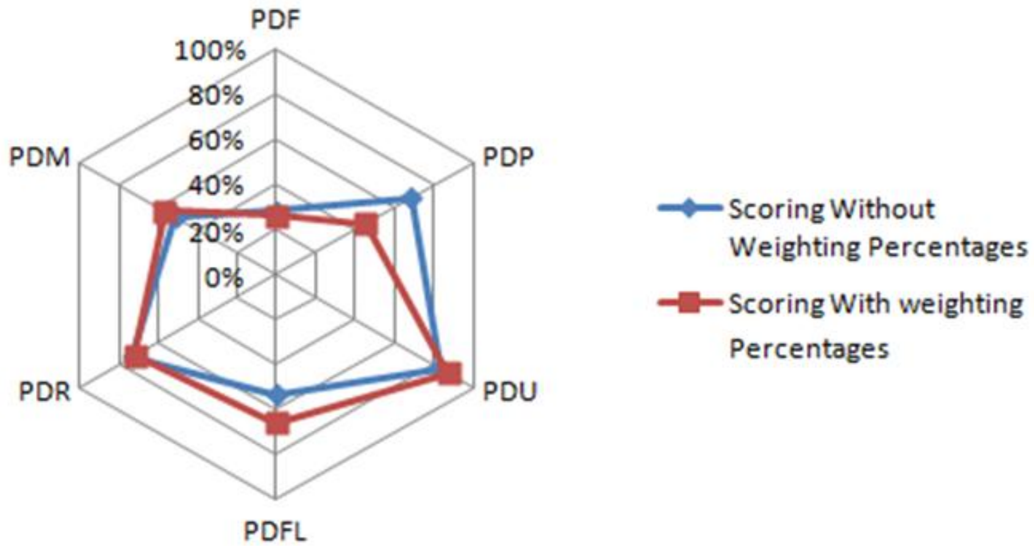


Figure 11:3: Diagram for Houghton Street

Houghton Street						
	PDF	PDP	PDU	PDFL	PDR	PDM
Scoring Without Weighting points	.28	.68	.83	.53	.73	.51
Scoring Without Weighting Percentages	28%	68%	83%	53%	73%	51%
Scoring With weighting	0.26	0.45	0.87	0.66	0.72	0.57
Scoring With weighting Percentages	26%	45%	87%	66%	72%	57%

Table 11-8: The points for each cluster on Houghton Street

PDF	PDP	PDU	PDFL	PDR	PDM
0	2.58	2.15	0	1.63	0
0	1.2	0.19	1.8	1.93	2.1
0	2	0.25	1.84	2.08	2.02
0.67	3	0.22	2.81	5.64	0
3.42	1.75	2.81	0.85		2.34
0	0		0		1.3
1.03	2.16		7.3		0.83
0	0				1.06
2.41	12.69				9.65
0					
0.83					
0					
0					
1.04					
0					
9.4					
3.612	**2.094**	**.323**	**1.111**	**0.785**	**0.177**
0.26	**0.45**	**0.87**	**0.66**	**0.72**	**0.57**

Table 11-9: The points for each cluster on Houghton Street

11.4.2 Cherry Mill Project

This project is designed for adults with mental health issues. It is a support house in Toxteth. The project comprises 10 bedrooms, a communal lounge, office/staff accommodation and a garden area with car parking.

The original property in Toxteth was about to be demolished. It had many issues, such as lack of space and sharing kitchen and bathrooms, lack of privacy, and the available space was dual function (eating and sleeping); as well as other issues.

This project has been maximised using environmental products and technologies to reduce services cost to achieve sustainable homes.

- Material

This project used external cavity masonry walls (A+) rated under the new BRE green guide, rain water recycling, durable material and is virtually maintenance free. It also used fully re-cyclable roof tiles; and high performance Westport windows with low embodied energy. Control of air leakage was also included, and roof insulation was considered.

- Environment

The project used large windows to minimise use of electricity and to give the sense that the space is spacious. Suitable lighting with sensors was selected. The project relied on natural ventilation through providing fresh air that could enhance the indoor environment. A green roof and water butts were provided.

Figure 11:4: Cherry Mill Project (Denovodesign, 2012)

Cherry Mill Project

Office Name	Denovo Design Ltd
Architect Name	Aitziber Gonzalez
Project Location	Windsor Street

Scoring

Implantation or consideration of factors in Design

0 ◄—— 5 ——► 10

Not implemented ◄—— Considered ——► Highly Implemented

Case study : Cherry Mill Project

	To what extents the following factors are implemented and considered in this design?	.S	T.P	D.P	W_s	Mean	W_{ms}
Passive Design Function-ality (PDF)	**AA3:** Use nearby landforms and structures for wind protection and summer shading	6	81	.54	.114	0.68	0.51
	AB2: Use low mass construction to allow rapid heat-up or cooling of structure	4			.316	1.26	
	AB3: Shape the building to maximise exposure to [winter sun and summer breezes]	7			.122	0.85	
	AB4: Use high mass construction with appropriate insulation to promote night ventilation	4			.336	1.34	
	AC1: Subdivide interior to create separate heating and cooling zones	4			.380	1.52	
	AC2: Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	4			.111	0.44	
	AC8: Consider interior surface colours and finishes for optimum day lighting	8			.103	0.82	
	AC9: Design plan to create buffer zones from the summer radiation	4			.185	0.74	
	AC10: Plan specific spaces or functions to coincide with solar orientation	5			.301	1.51	
	AC11: Narrow floor width to optimise natural ventilation	8			.303	2.42	
	AD2: Use skylight, light tube and clerestory for natural illumination	7			.083	0.58	
	AE4: Use Trombe wall or double façade to collect solar gain	4			.273	1.09	
	AE6: Minimise openings in envelope to reduce thermal gain	4			.305	1.22	
	AE8: Develop details to minimise air infiltration and ex-filtration	7			.346	2.42	
	AE10: Use louvred wall for maximum ventilation control	5			.334	1.67	
Passive Design Perfor-mance (PDP)	**BB2:** Select good colour to use	7	63	.79	.322	2.25	0.78
	BB6: Space layout enhances or interferes with well-being of occupants	9			.133	1.2	
	BC1: The temperature controls provide for the needs of different occupants	9			.286	2.57	
	BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants	8			.300	2.4	
	BD1: A comfortable internal air temperature	8			.175	1.4	
	BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast)	8			.284	2.27	
	BE4: The lighting quality enhances or interferes with well-being of occupants	7			.216	1.51	
	BE5: Atrium or rotunda control devices for optimum space comfort	7			.378	2.65	
Passive Design Usability (PDU)	**CA1:** Optimum position of service and passive element or equipment for operability	8	33	.83	.239	1.91	0.80
	CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	9			.024	0.22	
	CA3: Group homogeneous passive functions together for efficient operability	9			.028	0.25	
	CA4: Avoid slopes and steps of passive space floors	7			.032	0.22	
Passive design Flexibility (PDFL)	**DA3:** Allow ample floor-to-floor height for future modification	4	41	.68	.115	0.46	0.75
	DA9: Design passive space to respond to changes in climate conditions	7			.225	1.58	
	DB2: Design passive building to adapt for dysfunctional future utilisation	8			.230	1.84	
	DB3: Flexible access within and between passive spaces	10			.281	2.81	
	DB4: Consider the passive design that accommodates fundamental changes in user prefer-ences	8			.142	1.14	
	DB5: Design the passive space to cope with changes in flow of users	4			.118	.47	
Passive design Reliability (PDR)	**EA2:** Provide optimum drainage and venting to minimise accumulation of moisture	9	23	.77	.204	1.84	.76
	EA4: Select components that are resistant to environmental agents	8			.321	2.57	
	EB4: Use standardisation of passive design elements and materials	6			.260	1.56	
Passive Design Maintaina-bility (PDM)	**FA2:** Simplify interface of passive design elements and building façade	7	62	.78	.239	1.67	.78
	FA6: Design for ease to remove or replace lighting, ventilation and thermal comfort elements	8			.263	2.10	
	FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features	8			.253	2.02	
	FC3: Access routes of passive space for transport of maintenance materials	8			.090	0.72	
	FC4: Critical lighting, ventilation and thermal comfort element should be visible for inspec-tion	9			.292	2.63	
	FC5: All elements of the external passive building shell should be easy to access for mainte-nance and cleaning	8			.217	1.74	
	FC6: Optimise sizes for passive design openings for workmanship access	7			.165	1.16	
	FC7: Locate passive design elements where they are accessible for maintenance and repair	7			.177	1.24	

Result without weight	UCPBD tool = $\frac{\sum \text{PDF+ PDP+ PDU + PDFL + PDR+ PDM}}{440}$ *100	UCPBD tool = $\frac{\sum 81+63+33+41+23+62}{440} = \frac{303}{440} * 100$
	The Result = 68.86%	UCPBD Rate = Significant
Result with weight	C.Mean= $\frac{Meqan\ Equation}{\sum W_s\ of\ each\ culster*10} * 100$	C.Mean = $\frac{18.56 +16.25+2.6+8.3+5.97+13.28}{96.21} = \frac{64.96}{96.21} * 100$
	The Result = 67.51%	UCPBD Rate = Significant

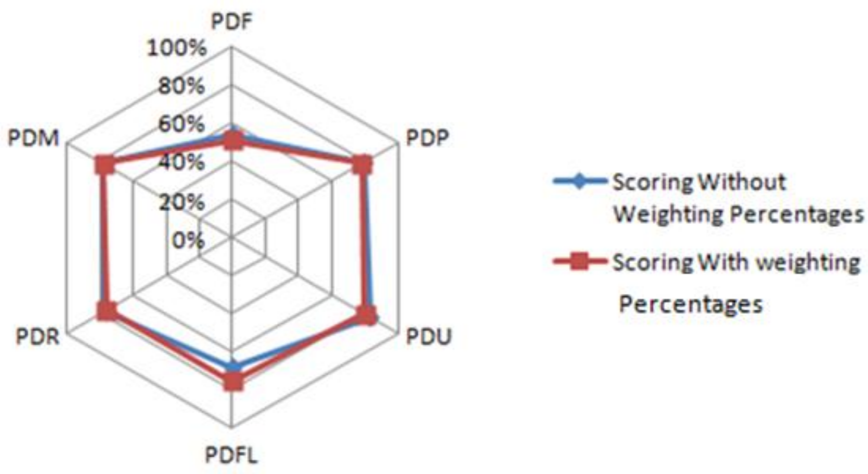


Figure 11:5: Diagram for Cherry Mill

Cherry Mill						
	PDF	PDP	PDU	PDFL	PDR	PDM
Scoring Without Weighting points	.54	.79	.83	.68	.77	.78
Scoring Without Weighting Percentages	54%	79%	83%	68%	77%	78%
Scoring With weighting	0.51	0.78	0.80	0.75	0.76	.78
Scoring With weighting Percentages	51%	78%	80%	75%	76%	78%

Table 11-10: The points for each cluster on Cherry Mill

PDF	PDP	PDU	PDFL	PDR	PDM
0.68	2.25	1.91	0.46	1.84	1.67
1.26	1.2	0.22	1.58	2.57	2.1
0.85	2.57	0.25	1.84	1.56	2.02
1.34	2.4	0.22	2.81	5.97	0.72
1.52	1.4	2.6	1.14		2.63
0.44	2.27		0.47		1.74
0.82	1.51		8.3		1.16
0.74	2.65				1.24
1.51	16.25				13.28
2.42					
0.58					
1.09					
1.22					
2.42					
1.67					
18.56					
3.612	**2.094**	**.323**	**1.111**	**0.785**	**0.177**
0.51	**0.78**	**0.80**	**0.75**	**0.76**	**.78**

Table 11-11: The points for each cluster on Cherry Mill

11.4.3 Fitzroy Street Project

The project was to replace demolish houses, known as “Victorian terraced”. The aim of this project was to provide houses which were high quality and energy efficient, with an attractive environment and with safety in mind. For this reason Denovo Design considered various issues, as follows: minimising wasting on the site, such as removal and disposal of soil should be maximised; provide buildings in terraced format, as this is the most ecologically sound and economical form of construction; reduce the cost through maintaining a standard floor level, maximising repletion of the components such as windows and doors, and prefinishing the components in the factory.

- Build Quality and Design

The design reflected the style of the traditional area as well as meeting “Lifetime Homes” criteria and achieved very good Eco homes. For this reason, various factors were considered, including energy conservation, providing a roof that is suitable to install P.V. solar panels, as well as using sun-pipe and traditional chimney; the external wall were traditional cavity type; minimising the use of plastic in the building; designing lighting and spacious housing for families; providing ramp access and wide parking; location of master bedroom and location of the key areas: all of these criteria and others are related to Lifetime Homes; these criteria can enhance homes for elderly people, considering outside issues such as recycling bins, clothes driers, providing strategies to conserve energy and water, and using local material.

- Housing Diversity and Sustainability

The project has been designed for both the elderly and families who are already living in this area, in order to provide a sustainable community [Site A – 15 no. 3 bed x 5 person family houses (shared ownership) and 5 no. 2 bed x 3 person bungalows (rent), Site B - 5 no. 3 bed x 5 person family houses (shared ownership), and Site C – 9 no. 3 bed x 5 person family houses (sale) , 4 no. 2 bed x 3 person bungalows (rent) and 5 no. 2 bed x 3 person family houses (shared ownership)]. These houses meet the “Lifetime Homes” criteria for enhancing life for the elderly and young people. There several measurement that have been considered, as follows: considering the boundaries between private and public areas, providing lighting in parking and communal spaces for security, providing sensor lighting, considering the location, redesigning the street to control car speeds, and involving the community.

- Landscaping and Use of Natural Features

To achieve this aim, the project provided flowering trees and shrubs for shade, climbing plants, durable grass, and the residents are able to hang baskets of flowers.

This project is achieving a very good level in terms of the Eco Homes scores.

Figure 11:6: Fitzroy Street Project (Denovodesign, 2012)

Fitzroy Street Project	
Office Name	Denovo Design Ltd
Architect Name	Arwa Al-Rekabi
Project Location	Ashton under Lyne/Manchester

Scoring

Implantation or consideration of factors in Design

0 ← 5 → 10

Not implemented ← Considered → Highly Implemented

Case study : Fitzroy Street Project

Cluster	To what extents the following factors are implemented and considered in this design?	F.S	T.p	D.p	W_s	Mean	W_{ms}
Passive Design Functionality (PDF)	**AA3:** Use nearby landforms and structures for wind protection and summer shading	3	82	.54	0.11	0.34	0.54
	AB2: Use low mass construction to allow rapid heat-up or cooling of structure	8			0.32	2.53	
	AB3: Shape the building to maximise exposure to [winter sun and summer breezes]	0			0.12	0	
	AB4: Use high mass construction with appropriate insulation to promote night ventilation	7			0.34	2.35	
	AC1: Subdivide interior to create separate heating and cooling zones	9			0.38	3.42	
	AC2: Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	8			0.11	0.89	
	AC8: Consider interior surface colours and finishes for optimum day lighting	10			0.10	1.03	
	AC9: Design plan to create buffer zones from the summer radiation	0			0.19	0	
	AC10: Plan specific spaces or functions to coincide with solar orientation	8			0.30	2.41	
	AC11: Narrow floor width to optimise natural ventilation	0			0.30	0	
	AD2: Use skylight, light tube and clerestory for natural illumination	10			0.08	0.83	
	AE4: Use Trombe wall or double façade to collect solar gain	7			0.27	1.91	
	AE6: Minimise openings in envelope to reduce thermal gain	5			0.31	1.53	
	AE8: Develop details to minimise air infiltration and ex-filtration	7			0.35	2.42	
	AE10: Use louvred wall for maximum ventilation control	0			0.33	0	
Passive Design Performance (PDP)	**BB2:** Select good colour to use	8	64	.8	0.32	2.58	0.74
	BB6: Space layout enhances or interferes with well-being of occupants	9			0.13	1.2	
	BC1: The temperature controls provide for the needs of different occupants	10			0.29	2.86	
	BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants	10			0.3	3	
	BD1: A comfortable internal air temperature	10			0.18	1.75	
	BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast)	7			0.28	1.99	
	BE4: The lighting quality enhances or interferes with well-being of occupants	10			0.22	2.16	
	BE5: Atrium or rotunda control devices for optimum space comfort	0			0.38	0	
Passive Design Usability (PDU)	**CA1:** Optimum position of service and passive element or equipment for operability	8	34	.85	0.24	1.91	0.82
	CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	9			.024	0.22	
	CA3: Group homogeneous passive functions together for efficient operability	9			.028	0.25	
	CA4: Avoid slopes and steps of passive space floors	8			.032	0.26	
Passive design Flexibility (PDFL)	**DA3:** Allow ample floor-to-floor height for future modification	8	50	.83	0.12	0.92	0.85
	DA9: Design passive space to respond to changes in climate conditions	8			0.23	1.8	
	DB2: Design passive building to adapt for dysfunctional future utilisation	9			0.23	2.07	
	DB3: Flexible access within and between passive spaces	9			0.28	2.53	
	DB4: Consider the passive design that accommodates fundamental changes in user preferences	8			0.14	1.14	
	DB5: Design the passive space to cope with changes in flow of users	8			0.12	0.94	
Passive design Reliability (PDR)	**EA2:** Provide optimum drainage and venting to minimise accumulation of moisture	8	22	.73	0.20	1.63	0.72
	EA4: Select components that are resistant to environmental agents	6			0.32	1.93	
	EB4: Use standardisation of passive design elements and materials	8			0.26	2.08	
Passive Design Maintainability (PDM)	**FA2:** Simplify interface of passive design elements and building façade	0	42	.53	0.24	0	0.58
	FA6: Design for ease to remove or replace lighting, ventilation and thermal comfort elements	8			0.26	2.10	
	FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features	8			0.25	2.02	
	FC3: Access routes of passive space for transport of maintenance materials	0			0.09	0	
	FC4: Critical lighting, ventilation and thermal comfort element should be visible for inspection	8			0.29	2.34	
	FC5: All elements of the external passive building shell should be easy to access for maintenance and cleaning	8			0.22	1.74	
	FC6: Optimise sizes for passive design openings for workmanship access	5			0.17	0.83	
	FC7: Locate passive design elements where they are accessible for maintenance and repair	5			0.18	0.89	

Result without weight	UCPBD tool = $\frac{\sum PDF+PDP+PDU+PDFL+PDR+PDM}{440} * 100$	UCPBD tool = $\frac{\sum 82+64+34+50+22+42}{440} = \frac{294}{440} * 100$
	The Result = 66.82%	UCPBD Rate = Significant
Result with weight	C.Mean= $\frac{Meqan\ Equation}{\sum W_s\ of\ each\ culster * 10} * 100$	C.Mean = $\frac{19.66+15.54+2.64+9.4+5.64+9.92}{96.21} = \frac{62.8}{96.21} * 100$
	The Result = 65.27%	UCPBD Rate = Significant

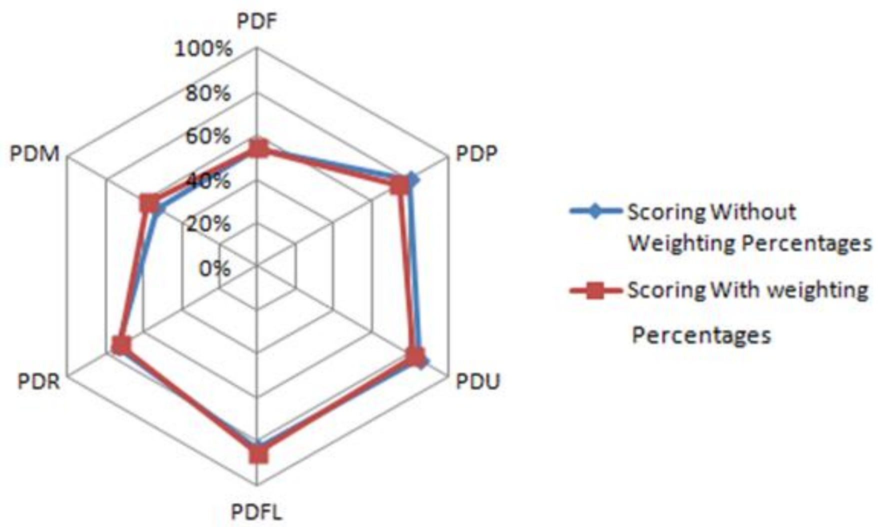


Figure 11:7: Diagram for Fitzroy Street

Fitzroy Street						
	PDF	PDP	PDU	PDFL	PDR	PDM
Scoring Without Weighting points	.54	.8	.85	.83	.73	.53
Scoring Without Weighting Percentages	54%	80%	85%	83%	73%	53%
Scoring With weighting	0.54	0.74	0.82	0.85	0.72	.58
Scoring With weighting Percentages	54%	74%	82%	85%	72%	58%

Table 11-12: The points for each cluster on Fitzroy Street

PDF	PDP	PDU	PDFL	PDR	PDM
0.34	2.58	1.91	0.92	1.63	0
2.53	1.2	0.22	1.8	1.93	2.1
0	2.86	0.25	2.07	2.08	2.02
2.35	3	0.26	2.53	5.64	0
3.42	1.75	2.64	1.14		2.34
0.89	1.99		0.94		1.74
1.03	2.16		9.4		0.83
0	0				0.89
2.41	15.54				9.92
0					
0.83					
1.91					
1.53					
2.42					
0					
19.66					
3.612	**2.094**	**.323**	**1.111**	**0.785**	**0.177**
0.54	**0.74**	**0.82**	**0.85**	**0.72**	**.58**

Table 11-13: The points for each cluster on Fitzroy Street

11.4.4 Tullis Russell Environmental Education (TREE) Centre

Atkins (2012) provides information about this project. This project has been funded by the Climate Challenge Fund and is a sustainable community building to consider sustainability issues. The total area of this project is less than 1.500 $m^{2.}$ The client was considered in the servicing strategy as well as in construction methods. There was a negotiation between the clients and design team. M&E Consulting Ltd calculated heating and ventilation rates. The building is a rectangular mono-pitched form with sun-space glazing to the south. Another strategy minimised use of synthetic material. The materials are familiar to SEDA members. The materials are as follows: Skene GlenEcolite blocks and ready mix (which uses PFA from Tullis Russell's power plant, all laid with lime mortar to displace OPC), Skaala doors and windows, Keim paints, marmoleum flooring, lime render, wood fibre and Warmcel insulation, Onduline bitumen based roof sheeting, Geberit HDPE waste pipes and clay drainage. The building is part insulated with straw bales that were bought and stored nearly a year in advance. Pallet end bricks were used in the drum. In addition, the building that stood on the site previously provided the glulam beams that form the main roof structure and the timber and mineral wool insulation that form the acoustic panelling to the main space and lecture theatre.

- Heating and Ventilation

One of the challenges is to provide a heating and ventilation strategy that can cope with permanent staff or with visitors joining, which could happen at any time. An overlapping system was the solution: the large space can cope with small groups with little additional ventilation. Louvres in the north side can allow the air to draw by stack effect through solar spaces. When very warm, the building will be cooled at night. This can be by providing air in the exhibition space and lecturer theatre. Timer and movement controls operate them by left them on to control fan speed. The pellet-fired Windhager boiler could be made smaller by using heat recovery ventilation of high level of thermal insulation. This means the need for a large thermal store will be minimised. The hot water is provided by supplying a hot solar panel to the external balcony, which is connected to the small thermal store.

- Lighting

A 3D model programme was used to accurately forecast the amount of lighting so that can be access in depth room in the winter season and shaded in the summer. Efficient artificial lighting has been located in several locations with assessment of the movement and luminosity levels. The latter is set at around 200-300 lux.

- Water

Rainwater is gathered in a large tank salvaged from Tullis Russell's factory. It is gathered by gravity and pumped into an internal header tank; the pump is powered by a small marine wind turbine and the water is distributed to all the WCs. The rest of the water is supplied via a filter from Tullis Russell's on-site bore hole.

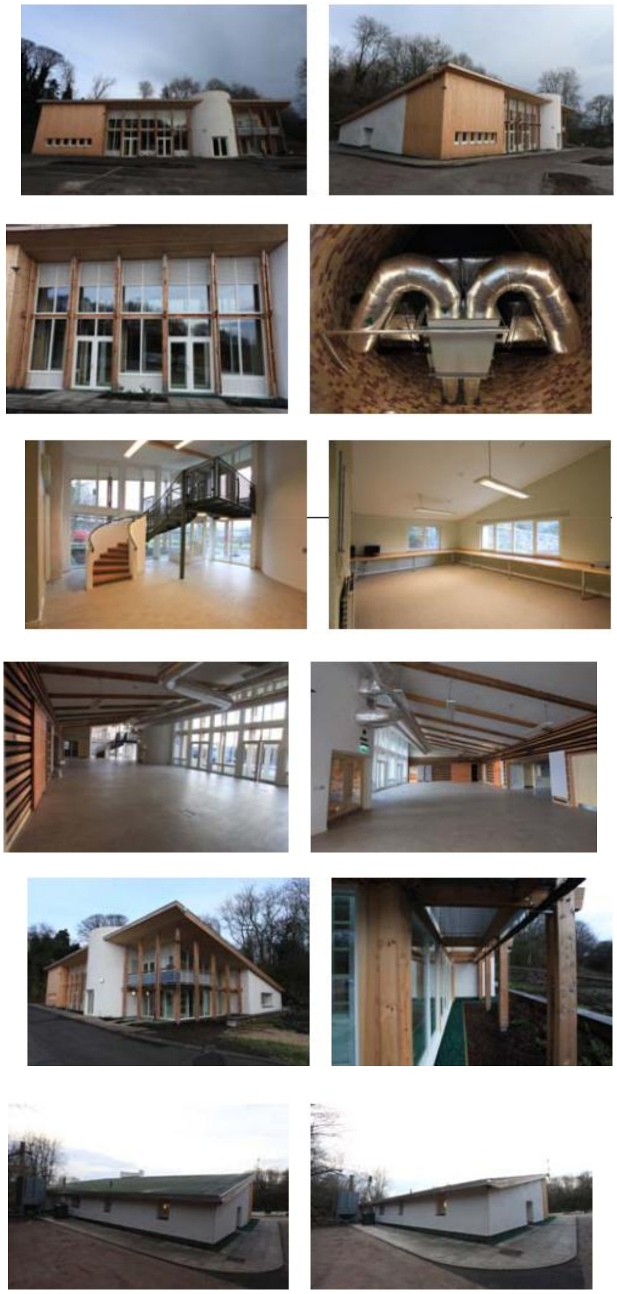


Figure 11:8: Tullis Russell Environmental Education (TREE) Centre (Atkins,2012)

Tullis Russell Environmental Education (TREE) Centre							
Office Name	Richard Atkins Chartered Architect						
Architect Name	Richard Atkins						
Project Location	Markinch, Glenrothes, fife Scotland						
Scoring Implantation or consideration of factors in Design							
0 ← 5 → 10							
Not implemented ← Considered → Highly Implemented							
Case study : Tullis Russell Environmental Education (TREE) Centre							
To what extents the following factors are implemented and considered in this design?		**F.S**	**T.P**	**D.P**	W_s	Mean	W_{ms}
Passive Design Functionality (PDF)	**AA3:** Use nearby landforms and structures for wind protection and summer shading	9	121	0.81	0.11	0.91	
	AB2: Use low mass construction to allow rapid heat-up or cooling of structure	10			0.32	1.58	
	AB3: Shape the building to maximise exposure to [winter sun and summer breezes]	8			0.12	1.22	
	AB4: Use high mass construction with appropriate insulation to promote night ventilation	0			0.34	3.36	
	AC1: Subdivide interior to create separate heating and cooling zones	10			0.38	3.42	
	AC2: Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	8			0.11	1.11	
	AC8: Consider interior surface colours and finishes for optimum day lighting	8			0.10	0.82	
	AC9: Design plan to create buffer zones from the summer radiation	10			0.19	0	
	AC10: Plan specific spaces or functions to coincide with solar orientation	7			0.30	3.01	
	AC11: Narrow floor width to optimise natural ventilation	10			0.30	2.42	
	AD2: Use skylight, light tube and clerestory for natural illumination	8			0.08	0.66	
	AE4: Use Trombe wall or double façade to collect solar gain	2			0.27	2.73	
	AE6: Minimise openings in envelope to reduce thermal gain	5			0.31	2.14	
	AE8: Develop details to minimise air infiltration and ex-filtration	8			0.35	3.46	
	AE10: Use louvred wall for maximum ventilation control	9			0.33	2.67	.82
Passive Design Performance (PDP)	**BB2:** Select good colour to use	9	52	0.65	0.32	0.64	
	BB6: Space layout enhances or interferes with well-being of occupants	8			0.13	0.67	
	BC1: The temperature controls provide for the needs of different occupants	8			0.29	2.29	
	BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants	3			0.3	2.7	
	BD1: A comfortable internal air temperature	8			0.18	1.58	
	BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast)	8			0.28	2.27	
	BE4: The lighting quality enhances or interferes with well-being of occupants	10			0.22	1.73	
	BE5: Atrium or rotunda control devices for optimum space comfort	9			0.38	1.13	.62
Passive Design Usability (PDU)	**CA1:** Optimum position of service and passive element or equipment for operability	2	35	0.86	0.24	1.91	
	CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	8			.024	0.192	.83
	CA3: Group homogeneous passive functions together for efficient operability	2			.028	0.28	
	CA4: Avoid slopes and steps of passive space floors	7			.032	0.288	
Passive design Flexibility (PDFL)	**DA3:** Allow ample floor-to-floor height for future modification	7	36	0.6	0.12	0.23	
	DA9: Design passive space to respond to changes in climate conditions	10			0.23	1.8	
	DB2: Design passive building to adapt for dysfunctional future utilisation	7			0.23	0.46	
	DB3: Flexible access within and between passive spaces	8			0.28	1.97	.60
	DB4: Consider the passive design that accommodates fundamental changes in user preferences	2			0.14	0.99	
	DB5: Design the passive space to cope with changes in flow of users	8			0.12	1.18	
Passive design Reliability (PDR)	**EA2:** Provide optimum drainage and venting to minimise accumulation of moisture	8	17	0.57	0.20	1.43	
	EA4: Select components that are resistant to environmental agents	8			0.32	2.57	
	EB4: Use standardisation of passive design elements and materials	2			0.26	0.5	.57
Passive Design Maintainability (PDM)	**FA2:** Simplify interface of passive design elements and building façade	10	60	0.75	0.24	1.91	
	FA6: Design for ease to remove or replace lighting, ventilation and thermal comfort elements	8			0.26	2.10	
	FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features	8			0.25	2.02	
	FC3: Access routes of passive space for transport of maintenance materials	8			0.09	0.18	
	FC4: Critical lighting, ventilation and thermal comfort element should be visible for inspection	9			0.29	2.92	
	FC5: All elements of the external passive building shell should be easy to access for maintenance and cleaning	10			0.22	1.74	
	FC6: Optimise sizes for passive design openings for workmanship access	8			0.17	1.32	
	FC7: Locate passive design elements where they are accessible for maintenance and repair	0			0.18	1.42	.80
Result without weight	UCPBD tool = $\frac{\sum PDF+ PDP+ PDU + PDFL + PDR+ PDM}{440} *100$	UCPBD tool = $\frac{\sum 121+52+35+36+17+60}{440} = \frac{321}{440} * 100$					
	The Result = 72.95%	UCPBD Rate = High Significant					
Result with weight	C.Mean= $\frac{Meqan\ Equation}{\sum W_s\ of\ each\ culster*10} * 100$	C.Mean = $\frac{29.51 +13.01+2.67+6.63+4.5+13.61}{96.21} = \frac{69.93}{96.21} * 100$					
	The Result = 72.68%	UCPBD Rate = High Significant					

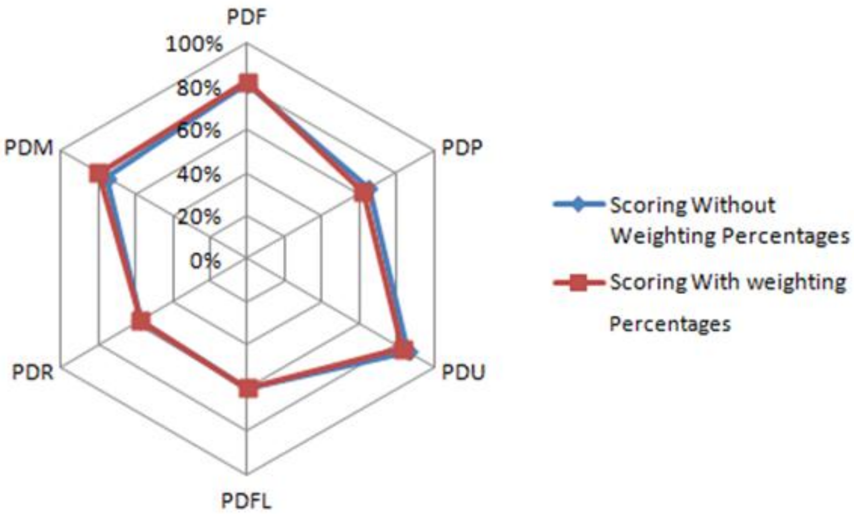


Figure 11:9: Diagram for the Tullis Russell Environmental Education (TREE) Centre

Tullis Russell Environmental Education (TREE) Centre						
	PDF	PDP	PDU	PDFL	PDR	PDM
Scoring Without Weighting points	.81	.65	.86	.6	.57	.75
Scoring Without Weighting Percentages	81%	65%	86%	60%	57%	75%
Scoring With weighting	0.82	0.62	0.83	0.60	0.57	.80
Scoring With weighting Percentages	82%	62%	83%	60%	57%	80%

Table 11-14: The points for each cluster on the Tullis Russell Environmental Education (TREE) Centre

PDF	PDP	PDU	PDFL	PDR	PDM
0.91	0.64	1.91	0.23	1.43	1.91
1.58	0.67	0.192	1.8	2.57	2.1
1.22	2.29	0.28	0.46	0.5	2.02
3.36	2.7	0.288	1.97	4.5	0.18
3.42	1.58	2.67	0.99		2.92
1.11	2.27		1.18		1.74
0.82	1.73		6.63		1.32
0	1.13				1.42
3.01	13.01				13.61
2.42					
0.66					
2.73					
2.14					
3.46					
2.67					
29.51					
3.612	**2.094**	**.323**	**1.111**	**0.785**	**0.177**
0.82	**0.62**	**0.83**	**0.60**	**0.57**	**.80**

Table 11-15: The points for each cluster on the Tullis Russell Environmental Education (TREE) Centre

11.5 Implication and Discussion

Applying the above tools helped the researcher to assess the PD projects. The assessment was based on two methods. The first method adapted the design quality indicators through considering the scores that have been given by the designers of these projects. The other method was by considering the weighting of each EUF separately. The impact of using the assessment tool is shown in the results of testing the projects. An excellent design is a design that meets EU needs through achieving the score of 10 for each EUF. Applying these methods showed to what extent the designers were meeting EU needs in various ATTs.

The result for the Houghton Street Project showed the difference on assessment with and without weighting. Without considering the weighting the result was moderate and with weighting it was satisfactory. The differences appeared on PDP where, with weighting, it formed 45%. PDP without weighting is 68%. Also, the flexibility of PD with weighting is 66% and without weighting it is 53%. These two ATTs show the differences on meeting EU needs and how these ATTs should be considered during the design, and when the designer did not pay enough attention to enhancing EU needs. The rest of the results are close to each other. However, the PDU is the highest EUF implemented by the designer. This appears in the results with weighting and without weighting.

For the Cherry Mill Street project, the results with weighting and without weighting are similar to each other. Even though the results with and without weighting achieved a significant level, the designer also considered EU needs in terms of passive deign usability, which appeared on the design with a percentage of 80% with considering the weighting and 83% without considering the weighting. The rest of the ATTs are close to each other and all of them are more than 76%, except PDFL and PDF. In terms of PDF, the designer has not considered some PDF factors. The percentage is around 50%. Also, PDFL is around 68% percentage. This demands a lot of consideration during design in order to increase the implementation of EUFs in this design; this will reflect on EU satisfaction as well as on building performance.

The Fitzroy Street project shows that the project achieved significance with and without weighting. The results are also similar to each other except PDF and PDM are the lowest considerations in the design; both of them are less than 60%. The designer considers the PDU and flexibility at the highest level, followed by performance and reliability. These ATTs are more than 70%.

The final case study achieved high significance both with and without weighting, although the results for the clusters are different. Based on the result, it can be seen that the designer paid attention to both PDF and usability ATTs, as both of them are more than 80%. Then the factors of PDM were considered, which are close to 80%. However, there is a lack of consideration of the factors of PDR, performance and flexibility.

Using this assessment can help the designer to avoid lack of consideration of EUFs. Also, it could maximise meeting EU needs and enhancing their satisfaction. The UCPBD tool is a tool that can help the designer to accede to the ambitions of the EU.

11.6 Summary of this Chapter

The assessment tool has been developed based on adaptation of the design quality indicators and the rate of both LEED and BREEAM tools, also, through using the weighting on each EUF. Then, it has been tested through four case studies which achieved different levels of assessment with weighting and without weighting. The result was achieved based on the scores that have been given by the designers of these projects as well as with weighting of each EUF based on data analysis. The testing tool proves to what extent this tool can help the designers to assess their design to establish whether or not it meets EU needs. This tool can be extended and developed in future research.

Chapter Twelve: Discussion and Conclusion

12.1 Discussion

The main objectives of this research were to determine the EUFs that affect designing PBD. The perceptions of the architects and designers about the effectiveness of the EUFs have been discussed in the previous chapters. This chapter will discuss the significance of the findings of the whole research from the literature review section to the data analysis section. For this reason, this chapter starts by summarising the research findings in relation to the research questions, starting with the questions of the development model, then the findings and discussion, before ending up with the development of an assessment tool from the EUFs that have been identified.

12.1.1 User Centred Design

Research question (1)

What are the suitable methods for modelling, capturing and integrating EUFs into PBD?

The literature review shows that there are some theories, approaches and methods that explain different methods for considering EU needs. In terms of the architectural theories and design approaches, as reviewed in Chapter 2, some of them have taken user needs into account and some of them have not. One of the theories that consider EU needs is post-occupancy evaluation as defined by (Preiser et al, 1988, as cited in Blakstad, 2010). This theory looked to EU feedback and needs after a building was occupied. This goes against the main focus of this research, which is bridging the gap between EU needs and PD before posting the design. Through investigation, there are no theories that bridge the gap between EU needs and PD during the design process. Another theory that considers EU needs is the ergonomics theory as refrred by Hussain and Hussain (1984, as cited in Carey, 1988, p.624). This theory is considered to fulfil EU comfort. This is dissimilar to what this research is looking for, which is to meet EU wishes from different ATTs.

Accessibility is one of the EU's needs. Attaianese and Duca (2010) claimed that accessibility is related to ergonomic issues. The accessability EUFs are determined as a way of finding safety during an emergency and as a design for all, including for people with special needs. The lack of investigation and research of EU needs and bridging them with the PD process is the main concern of this research. This confirms what several authors have referred to as the lack of research in the area of this research, as introduced in the introduction chapter such as TSB (2009) when they referred to the role of the designer in integrating the EU within the design. in addition to that, Levin (2003) The objective of this research is to seek a method that can help the designer to be a basis to fill this gap. For this reason, it has looked at attempts in other research fields. For example, one of the IT theories is UCD. This method is applied in the IT industry to fulfil EU needs. The aim of this theory is the same as the aim of the current research. In addition to that, several standards were developed based on UCD theory.

ISO 13407 and ISO 9126 were selected because their content fits in with building industry contents. These parameters make this theory acceptable to use. These theories and other architectural theories do not consider the EU needs from different ATTs and perspectives; also, there is no systematic process that the designer could follow to meet EU needs, as shown in Chapter 2. Both of these reasons made the researcher select the ISO 13407 design process and the ISO 9126 design ATTs, as shown in Chapter 3. Using the theories to link the EU needs with PDs was the solution that can answer all of the research questions and the research problem. For this reason, the researcher checked the theories based on the ATTs of the model. The result was that there is no approach that met the proposed model.

12.1.2 User classification

Despite an increasing interest in building performance assessment and sustainability evaluation, the majority of research tends to concentrate on one or two aspects, such post-occupancy evaluation, environmental issues, etc. Various researchers are interested in performance assessment. However, considering Us and EUs' needs was not part of the various assessments tools. There is also a lack of differentiation between Us and EUs in the design of building assets. Various definitions and concepts are attributed to Us and EUs. The literature review of this section highlighted that there are a variety of existing terminologies to describe the U. In terms of IT there are various classifications of the U, for example, direct U, indirect U and other stakeholders (Geumacs, 2009, p.29). One of the previous researchers has also organised the U into three levels based on their experience (Nardi and Miller, 1991). This can be seen from the different views of classification of U. The Us whose needs have to be considered by the designer should be classified in a coherent way because there are many designers who are looking to the actual U (the building occupant). Looking to this particular type of the U could lead to designing a building that is complex and difficult. For this reason, making the definition of U wider becomes an essential requirement in this research through reviewing the existing terminologies in both the building industry and the IT industry.

In this research the U is classified into two types: EUs and U. The EU is the actual U of the building. The U can be part of the design whether they are stakeholders, maintenance workers or other kind. One of the definitions of EU in IT, which is defined by (Webopedia, 2012), they showed that the U can be widely defined. From all the definitions in the literature review, the researcher extracted an inclusive view, that is, the Us and EUs in the building industry. This was necessary to help the researcher to accurately map out the Us' predispositions, expectations, needs, motivation, etc. By using the EU needs as benchmarks for design assessment, the potential for improving the indoor environment and U well-being in buildings is enormous. UCPBD has been proposed as a design paradigm that can help the architects to meet the majority of EUs' needs in terms of functionality, performance, usability, flexibility, reliability and maintainability.The researcher hypothesises that any design that includes the suggested factors will lead to a high level of EU satisfaction and high building performance. In addition to that, through discussion with many designers about the U of the design, the direct answer was usually that they referred to the occupant of the building, who is the actual U. The importance of considering different types of U will lead to increasing the high performance of the design that meets the requirements of all U types. In contrast, only considering the actual EU could lead to ignoring some design requirements that are not easy to handle in the future, such as maintenance issues.

12.1.3 Passive design strategies

- What are PBD strategies and how will be related them to the EU needs?

The environmental issues lead to maximising using energy. One approach that has been applied is the PDS. Based on reviewing the PDS in a simple sense this approach is developed to rely on natural environmental conditions more than on mechanical means. The purpose of reviewing PD is because the main focus of this research is to bridge the gap between the PD and EU needs. For this reason, the research looked to investigate the PDS before looking at EUFs. Through reviewing the PDS, it was found that various authors looked at PL, PV and PH, as shown in Chapter 3. One of the unexpected results is through reviewing various definitions for each PDS separately. Not one of these dimensions considered both types of U. In addition to that, through comparing several definitions, it was found that some of them looked to the actual U but not as their main concern or as the centre of the research; for example, thermal comfort is defined in British Standard BS EN ISO 7730 as cited in the Health & Safety Executive (1999) . That is to say, we cannot consider the environment and ignore the EU or vice versa. However, there is no clear placement for the U. In terms of day lighting, one of the definitions is that defined by (Li and Tsang, 2008), as introduced in Chapter 3. This definition has considered day lighting as a balance between U demand and energy needs. One of the findings of this review of the strategies of these dimensions is that there are some strategies that have a dual function; providing the window and glazing strategies is a good example. BIM (2011) states that the ratio of the glazing should be for optimum natural lighting or ventilation without creating any overheating or cooling. To avoid a repetition of the review of the strategies, the researcher classified the strategies under five S-ATTs, which are site, orientation and vegetation, building form, space planning, roof and façade, as illustrated in Chapter 4. This kind of classification can help the designer to meet EU needs in terms of the PLVT. Also, this classification helped the researcher to organise the research questionnaire in a coherent, simple and comprehensive way, as shown in Chapter 10. The result of this review was to determine the PDS, which were classified as the three dimensions to be the core of the conceptual model; and then their strategies were listed under the five S-ATTs of PDF. In this research, the vision of looking to PDS in relation to EU is more widely. For this reason, this section takes an essential place in this research because of the lack of interaction between the PDS and EU needs.

12.1.4 Passive design human attributes

Interaction of the EU needs with PD is one of the challenges of the research: to find a classification that confirms fulfilment of the EU needs. Based on reviewing the UCD theory, the researcher found ISO 9126 was one of the standards that met EU needs through various ATTs, as shown in Chapter 3. The ATTs of this standard are functionality, efficiency, usability, portability, reliability and maintainability. These ATTs were used because of their similarity with ATTs in the building industry. These ATTs were used as a link through which to investigate EU needs with some modification of both efficiency and portability to become performance and flexibility, respectively. Looking to EU needs through various ATTs means satisfying them and matching their aspirations from different perspectives. This also can lead to fulfilling all EU types (as classified in the previous sections) in order to investigate their relationship to each ATT separately. Investigation of EUFs through these ATTs was a challenge in order to link them with PDS. This challenge took the highest percentage of the main body of the research - from Chapter 4 to Chapter 9. The total number of the EUFs is 132 EUFs; they are divided with regard to their relevancy to the six ATTs. The review of these EUFs was based on the literature review for each ATT. Furthermore, the EUFs seem to be a necessity. EUFs were identified based on comparing the proposed model with the architectural theories, brainstorming with the supervisor of this research, and utilizing the experience of the researcher in architectural design. The purpose of extracting this amount of EUFs was in order to use them when designing the questionnaire. This classification considered the EU needs from different perspectives, unlike the theories that meet EU needs based on one or two ATTs. These ATTs will influence the practising architects to look at design requirements from different trends. These ATTs can lead to delivery of a design that can be adapted through the whole life cycle.

12.1.5 User Centred Passive Building Design Model

Research question (5)

What is the conceptual model that can help the designer to meet user needs during design PBD?

Based on reviewing the previous sections, a concept was proposed to help the designer to meet EU needs in relation to PDS. Looking at the existing approaches and theories was one of the stages in proposing this model. The findings of the PDS led to classifying them into three PD dimensions to be a core of the proposed model. This is the starting point of the research: to determine the EU needs in relation to them. One of the components of the model is the PDHAs, as introduced in the previous section. After identification of these two components of the UCPBD model, the researcher looked at the process that the designer should follow to ensure meeting EU needs before posting the design. This section was the second stage of the development model. Through reviewing the UCD theory, the researcher selected ISO 13407, which is one of the standards that the designer should go through to meet EU needs. The design process is designed in a way that the designer should follow when they implement the PDS. This process developed in a way that involved the design ATTs and going through each ATT when selecting, implementing strategies or designing PBD. The process can also lead to reducing EU complaints. The proposed model is a merger of three components, which are PDS, UCD process and PDHAs. The proposed model attempts to meet EU needs to reduce EU complaints. In terms of the other theories and tools, usually they concentrate on environmental issues more than on human issues. This model differs from other models based on several points, which are concept, analysis, assessment, design process, U classification and model development. There are several questions that have been identified in order to develop the conceptual model. These questions are listed under each section separately. UCPBD in this research embraced EUFs for PDHAs, as shown (UCPBD questionnaire in Appendix B). The EUFs were presented based on the definition of UCPBD; and they have been selected to be considered in the early design stages. Application of the EUFs and PDS will lead to enhance meeting U needs.

12.1.6 Data analysis discussion

The collected data has been analysed using scientific methods. The scientific methods went through four stages, which are descriptive analysis, ranking the results, testing the hypotheses and data reduction. These were obtained through statistics and using SPSS and Excel software (see Chapters 6-9). These methods were used to answer the questions in the following sections. These questions have been answered by using the descriptive methods, ranking methods, ANOVA method, and correlation component with EUFs. These methods have been analysed through using SPSS for analysing the collected data. These will be explained in detail in the following sections through answering the following question:

What are the most effective EUFs on UCPBD?

The research analyses the architect respondents' views of the effectiveness of the EUFs of UCPBD. The EUFs are developed and extracted based on reviewing the literature, particularly from Chapter 4 to Chapter 9. The EUFs that have been selected are listed in these chapters together with their references. The questionnaire responses were analysed for each ATT in order to determine the highest effective EUFs. The descriptive analysis part shows us the most effective EUFs. SPSS methods were used to calculate the mean value and standard deviation to find out the highest effective EUFs. The highest effective EUFs based on the result of the descriptive analysis are listed in Table 12-1 based on their mean value.

Attributes	Code	End User factors of Passive Design Functionality	Mean	Std. Deviation	Ranking
Passive design Functionality	AA2	Orient the building for optimum lighting, ventilation and thermal comfort	4.51	.896	1
	AB3	Shape the building to maximise exposure to [winter sun and summer breezes]	4.06	.921	9
	AC3	Use central atriums, courtyards and lobbies (elevators, and stairs can be locate in central areas) for optimum ventilation	4.15	.822	8
	AC4	Provide vertical air shafts/stacks, and central exhaust paths to promote	4.05	.866	10

		interior airflow			
	AC9	Design plan to create buffer zones from the summer radiation	4.18	.706	6
	AC10	Plan specific spaces or functions to coincide with solar orientation	4.25	.756	4
	AD2	Use skylight, light tube and clerestory for natural illumination	4.18	.744	7
	AE9	Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort	4.31	.875	2
	AE12	Orient openings to facilitate natural ventilation	4.26	.809	3
	AE16	Provide high levels of insulation in the façade and building envelope to reduce summer conductive gain and to preserve internal heat	4.20	.833	5
passive Design Performance	BA1	Utilizing views and orientation	4.34	.694	3
	BD1	A comfortable internal air temperature	4.49	.632	1
	BD2	The air quality in space enhances or interferes with well-being of occupants	4.33	.679	4
	BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)	4.31	.726	5
	BE2	The adequacy of natural light in spaces	4.36	.787	2
Passive design usability	CA5	Incorporate passive design technologies which are easy to operate by multiple users	4.08	.836	3
	CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)	4.26	.762	1
	CB2	Consider safety, health and physical well-being needs for multiple users of passive buildings	4.22	.783	2
Passive design flexibility	DA1	Passive building structure should be upgradable for future regulations and safety procedures	3.90	.957	2
	DA7	Design a passive building that responds to the increasing pressures of rapid changes in technology shifts	3.87	.920	3
	DA9	Design passive space to respond to changes in climate conditions	4.07	.945	1
Passive Design Reliability	EA2	Provide optimum drainage and venting to minimise accumulation of moisture	4.10	.741	3
	EA6	Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation	4.20	.822	1
	EB2	Use high quality material with long service life to handle passive functions	4.11	.902	2
Passive design Maintainability	FA7	Design for ease to adjust lighting, ventilation and thermal comfort physical element features	4.05	.833	2
	FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity	4.12	.763	1
	FC2	The interior of the passive building is designed to be easy to clean and maintain	4.03	.818	3

Table 12-1: The highest effective factors in Chapter 11

These results are expectable because all of them were selected based on an accurate literature review. One of the main finding in Chapter 11 is that the mean values of all EUFs are more than 3. This means all of the EUFs can be considered as essential EUFs.

12.1.6.1 Comparing the results

During the process of the design questionnaire, one of the questions asked is to identify the professional role of the architects and their experience. The professional role includes practising architect, academic and practising architect, and academic architect. The respondents' experience includes three types, which are 0-5 years, 5-10 years, and more than 10 years. This classification has been used to see the difference between the perceptions of respondents' rankings as well as to test the hypotheses of EUFs based on both architects' professional roles and experience groups. The survey of architects shows different rankings in terms of their experience and professional role. This comparison has been shown in Chapter 7, using the rankings to see the differences and similarities between the architects' responses.

Ranking of passive design Functionality

This is based on the ranking of the EUFs of this attribute, as shown in Table 12-2. For practising architects, four EUFs were different from the other EUFs in the other five groups' rankings. The EUFs are AC2, AC7, AD1, AE5 and AE8. These EUFs were selected based on the literature review (as shown in Chapter 4) and their ranking was varied, compared with the other groups. Also, the dissimilar EUFs for the academic and architect practising group were four EUFs, which are AA3 AB3, AC2 and AE16. For academic architects, AC9 and AE12 were different from the other groups, based on their ranking. The interpretation of the differentiation between these results is the relationship between the architects and the building industry and the degree of experience, which will be clarified as follows. The group of architects with between 0-5 years' experience had only two EUFs where their ranking was different than the other five groups. These EUFs are AC14 and AD5. For the architects who have 5-10 years' experience, their ranking differed in 10 EUFs compared to the other groups. These EUFs namely are AA1, AA3, AC9, AD6, AE3, AE5, AE7, AE9, AE11 and AE16. For the last group - the architects who have more than 10 years' experience - the ranking of the whole EUFs shows that there is no clear difference. Also there is no need to pay attention to their results. These differences between the groups reflect the interests and the awareness of the different groups, and also how their experience and professional role can affect their ranking of the PDF.

End user factors	**L1 T.R:29**	**L2 T.R:49**	**L3 T.R:32**	**M1 T.R:33**	**M2 T.R:23**	**M3 T.R:54**
AA1					+	
AA3		+			+	
AB3		+				
AC2	+					
AC7	+					
AC8		+				
AC9			+		+	
AC14				+		
AD1	+					
AD5				+		
AD6					+	
AE3					+	
AE5	+				+	
AE7					+	
AE8	+					
AE9					+	
AE11					+	
AE12			+			
AE14						
AE16		+			+	

Table 12-2: The highlighted end user factors ranking in passive design functionality.

Ranking of passive design Performance

This is based on the ranking of the EUFs of this ATT, as illustrated in Table 12-3. For practising architects two EUFs were different from the rest of the EUFs in the other five groups' rankings. The EUFs are BD2 and BE1. These EUFs were selected based on the literature review, as shown in Chapter 5. Also, the dissimilar EUF for academic architects was one EUF, which is BC2. The group of architects with between 0-5 years' experience had three EUFs where their ranking differed from those of the other five groups. These EUFs are BD3, BE2 and BF1. For the last two groups (the architects with 5-10 years' experience and more than 10 years' experience), there is no a clear differences. However, this difference between the rest groups reflects the architect interests and the level of their awareness about the EUFs.

End user factors	L1 T.R:29	L2 T.R:49	L3 T.R:32	M1 T.R:33	M2 T.R:23	M3 T.R:54
BC2			+			
BD2	+					
BD3				+		
BE1	+					
BE2				+		
BF1				+		

Table 12-3: The highlighted end user factors ranking in each passive design performance

Ranking passive design Usability and Flexibility

Based on the ranking of the EUFs of these ATTs, as shown in Table 12-4, in terms of usability ATT, for practising architects one EUF was different from the other EUFs in the other five groups' rankings. The EUF is CB1. This EUF has been selected based on the literature review, as shown in Chapter 6; and the ranking varies from the other groups. In terms of the flexibility, two EUFs were highlighted: DB1 and DB6.These EUFs are dissimilar to the other five groups' rankings, based on the ranking of practising architects. Also, the dissimilar EUFs for academic and practising architects were two EUFs, which are DA4 and DA10. For academic architects only one EUF is highlighted as a dissimilar EUF, which is DB7. The group of architects who have between 0-5 years' experience selected two EUFs where their ranking differed to the other five groups. These EUFs are DB4 and DB7. For the last two groups, the architects who have 5-10 years' experience and more than 10 years' experience ranked DA1, DA2, DA3 and DB1 and DA10 differently. These EUFs are different than the other groups'. This also could reflect how the architects' experience and professional role can affect the PDP ranking. These EUFs are selected based on a literature review, as shown in Chapter 7.

End user factors	L1 T.R:29	L2 T.R:49	L3 T.R:32	M1 T.R:33	M2 T.R:23	M3 T.R:54
CB1	+					
DA1					+	
DA2					+	
DA3					+	
DA4		+				
DA10		+				+
DB1	+				+	
DB4				+		
DB6	+					
DB7			+	+		

Table 12-4: The highlighted end user factors ranking each in passive design usability and flexibility

Ranking of passive design Reliability

Table 12-5 illustrates the ranking of the EUFs of this ATT. For academic architects EUFs were different from the rest of the EUFs in the other five groups' rankings. The EUFs are EA1 and EB2. These EUFs have been selected based on the literature review, as reviewed in Chapter 8; and the ranking of it was different than the rest of the groups. Also, the dissimilar EUF for architects with between

0-5 years' experience was EA4. For architects who have between 5-10 years' experience, EA3 and EA7 are different from the other groups, based on their ranking. For the architects with more than 10 years' experience, only one EUF was ranked different to the other groups. The EUF namely is EB3. This difference between the groups reflects the interests and the awareness of the different groups, and also how their experience and professional role can affect the ranking of the PDR.

End user factors	L1 T.R:29	L2 T.R:49	L3 T.R:32	M1 T.R:33	M2 T.R:23	M3 T.R:54
EA1			+			
EA3					+	
EA4				+		
EA7					+	
EB2			+			
EB3						+

Table 12-5: The highlighted end user factors ranking in each passive design reliability

Ranking of passive design Maintainability

Table 12-6 illustrates the ranking of the EUFs of this ATT. For practising architects, one EUF was different from the rest of the EUFs in the other five groups' rankings. This EUF is FB2. Also, the dissimilar EUFs' ranking for architects with between 5-10 years' experience were FA1, FA7, FB2, FC2 and FC7. This difference between the groups reflects the interests and the awareness of the different groups. Their experience and professional role can affect the ranking of the PDM. The differences between these EUFs are shown in the following table.

End user factors	L1 T.R:29	L2 T.R:49	L3 T.R:32	M1 T.R:33	M2 T.R:23	M3 T.R:54
FA1					+	
FA7					+	
FB2	+				+	
FC2					+	
FC7					+	

Table 12-6: The highlighted end user factors ranking in each passive design maintainability

12.1.6.2 Testing the hypotheses

Chapter 9 tested the hypotheses for each ATT separately using the ANOVA one way analysis based on architects' professional role and experience. The results are shown in the following table:

Attributes	Analysis based on Professional role	Analysis based on Years' Experience
Passive Design Functionality	-	AA2,AC11,AC12,AE9
Passive Design Performance	BB1 and BG2	BE3
Passive Design Usability	-	CA2
Passive Design Flexibility	DA8	DA10
Passive Design Reliability	EB2	EB3
Passive Design Maintainability	-	FA7

Table 12-7: The rejected end user factors

13 EUFs have been rejected, which is an acceptable result in both directions. In terms of professional role, only 4 EUFs out of the 132 EUFs were rejected. In addition to that, 9 EUFs out of 132 EUFs were rejected based on the architects' experience. This result is unexpected result because all of

these EUFs were selected based on a literature review, as shown in Chapters 4. This result shows that the rejected EUFs are more based on the architects' experience. This could be related to their experience and may fluctuate based on types of experience. The experience and awareness could play a clear role in decreasing the rejected EUFs. This method helped the researcher to identify the null and rejected EUFs.

The justifications for the rejected factor are listed Table 12-8 and Table 12-9:

Research Question	Is there a significance difference between the architects' opinions regarding the effectiveness of the EUFs that were identified based on their professional role?
Hypotheses	1. A_2: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design performance S-ATTs: site performance, space performance, thermal comfort performance, natural ventilation performance, day lighting performance, acoustic performance and adequacy and consumption strategies design factors".based on their professional role. *2.* A_4: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design flexibility S-ATTs: future adaptability and flexible space" based on their professional role. 3. A_5: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design reliability S-ATTs: durability, material reliability and resilient design factors" based on their professional role.
Results	The result of analysis by using one way ANOVA determined that there were significant differences between the architects' perceptions on some EUFs, which are namely BB1, BG2, DA8 and EB2, based on their professional role.
Researcher's Perceptions	• The three EUFs were selected based on a literature review, as follows: BB1: Select good colour to use (Ministry for the Environment, 2008); BG2: Utility PD cores uniformly designed and vertically stacked (Centre For the Built Environment, NA); DA8: Design passive space that responds to changes in spatial dimensions (volume) (Slaughter, 2001); EB2: Use high quality material with long service life to handle passive functions (ABCB, 2006). For this reason, the results of these EUFs are unexpected. • The respondents were concentrated on the other end user factors. Four out of the132 EUFs were rejected. • The rejected EUFs are related to three types of ATT, which are not covered in the other three types of ATT. • The different professional roles could affect rejection of these EUFs because the perception of the architects who are practising only is different than the architects who are related to academia.
Conclusion	The following null hypotheses, A_2, A_4 and A_5 were rejected.

Table 12-8: Research Question (8) The rejected hypothesis based on professional role for the first part of the survey: A_2, A_4 and A_5 Results

Research Question	Is there a significant difference between the architects' opinions regarding the effectiveness of the EUFs that were identified based on their experience?
Hypotheses	A_1: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design functionality S-ATTs: site, orientation and vegetation, building form, space planning, roof and façade" based on their experience. A_2: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design performance S-ATTs: site performance, space performance, thermal comfort performance, natural ventilation performance, day lighting performance, acoustic performance and adequacy and consumption strategies design factors based on their experience. A_3: There is no statistically significant difference between the architects' perceptions

	regarding the level of effectiveness of EUFs of "passive design usability S-ATTs: operability and human behaviour design factors" based on their experience. A_4: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design flexibility S-ATTs: future adaptability and flexible space" based on both their professional role and experience based on both their experience. A_5: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design reliability S-ATTs: durability, material reliability and resilient design factors" based on their experience. A_6: There is no statistically significant difference between the architects' perceptions regarding the level of effectiveness of EUFs of "passive design maintainability S-ATTs: standardisation, material and accessibility design factors" based on their experience.
Results	The result of analysis by using one way ANOVA determined that there were significant differences between the architects' perceptions on some end user factors, which are namely AA2, AC11, AC12, AE9, BE3, CA2, DA10, EB3 and FA7, based on their experience.
Researchers Observation	• The nine end user factors were selected based on a literature review as follows: AA2: Orientation of the building for optimum L.V.T (United States Department of Energy, 2000; BIM, 2011; and Ministry for the Environment,2008); AC11: Narrow floor width to optimise natural ventilation (Ministry for the Environment, 2008; and Lechner, 2009); AC12: Provide solar-oriented interior zone to store and maximise solar heat gain (Kurtbas and Durmus, 2008; and Garcia-Hansen et al, 2002); AE9: Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort (Ministry for the Environment, 2008; and Bateson and Hoare Lea, 2001); BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast) (Fowler et al, 2005; Khalil and Husin, 2009); CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas) (Nylåna, 2005); DA10: Design passive layout based on future use scenarios (Niklas & Bengt, 2009); EB3: Consider the rate of expansion/contraction of material of passive design strategies (ABCB, 2006); FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features (Northumberland National Park Authority, 2006). For this reason, the results of these end user factors are unexpected. • The respondents were concentrated on the other end user factors. Nine out of the132 end user factors were rejected. • The rejected factors are related to six main attributes. • The different years of experience of the architects could affect the rejection of these end user factors because the perception of the architect who has between 0-5 years' experience is different than the architect who has more than 10 years' experience or between 5-10 years'.
Conclusion	The following null hypotheses, A_1, A_2, A_3, A_4, A_5 and A_6, were rejected.

Table 12-9: Research Question (8) The rejected hypotheses based on architects' experience for the first part of the survey: A_1, A_2, A_3, A_4, A_5 and A_6 Results

Chapter 9 tested the hypotheses for each ATT separately through using the ANOVA one way analysis based on architects' professional role and their experience. The results shown in Table 12-10:

Attributes	Analysis based on Professional role	Analysis based on Years' Experience
Passive Design Functionality	-	-

Passive Design Performance	-	+
Passive Design Usability	+	+
Passive Design Flexibility	-	+
Passive Design Reliability	-	-
Passive Design Maintainability	-	-

Table 12-10: The rejected end user factors

Four ATTs were rejected, which is not an acceptable result especially based on experience. In terms of professional role only one ATT has been rejected, which is PDU. This result is unexpected because the architects usually claimed that they fulfil it. The unexpected result is also rejected based on the other hypothesis which is based on architects' experience. This ATT particularly is one of the main issues that the designers usually take into account. In terms of testing the ATTs based on the experience of the architect respondents' result three ATTs were rejected. In addition to usability, another two ATTs were rejected, namely performance and flexibility. This could depend on their experience. Experience and awareness could play a clear role in decreasing the rejected ATTs. This method helped the researcher to identify the null and rejected EUFs. The explanation for each group appears in Tables 12-11 and 12-12 for each ATT, as listed below:

Research Question	Is there a significant difference between the architects' perceptions when they keep end user needs in their mind in relation to passive lighting, ventilation and heating when they specify passive design attributes based on their professional role?
Hypothesis	B3: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDU based on their professional role.
Results	The result of analysis by using one way ANOVA determined that there were significant differences between the architects' perceptions on some end user factors which are namely GC, based on "their professional role".
Researcher's Observation	• The six main attributes were determined based on ISO 9126 and were investigated one by one based on a literature review. For this reason, the result of the passive design usability attribute is unexpected. • The respondents were concentrated on the other attributes. • Only one of the six attributes was rejected. In discussion with the architects, they claimed that they usually consider this attribute. For this reason, the result is surprising to the researcher. • The different professional roles could affect the rejection of this attribute because the perception of the architect who is practising only could be different than the architect who is related to academia. It depends on their interaction with the design and building industry. However, this is not acceptable. Even in the architectural education, considering user needs and providing a usable building should be a clear target.
Conclusion	The following null hypotheses A_3 was rejected.

Table 12-11: Research Question (9) The rejected hypothesis based on architects' professional role for the first part of the survey: A_3 Results

Research Question	Is there a significant difference between the architects' perceptions when they keep end user needs in their minds in relation to passive lighting, ventilation and heating when they specify passive design attributes based on their experience?
Hypotheses	B_3: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDU based on their experince. B_4: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDFL based on their experince.

	B_5: There is no obvious difference between the architects' perceptions regarding the considration of EU aspirations in PDR based on their experince.
Results	The result of analysis by using one way ANOVA determined that there were significant differences between the architects' perceptions on some end user factors, which are namely GB, GC and GD, based on their experience.
Researchers Observation	• The six main attributes were determined based on ISO 9126 and investigated one by one based on a literature review in relation to building design. For this reason, the results of the passive design performance, passive design usability and passive design flexibility attributes are unexpected. • Three of the six attributes were rejected. This result is unexpected; in discussion with the architects, they claimed that they usually consider this attribute For this reason, it is surprising to the researcher. Flexibility and performance include various significant factors which should be rejected. Architects should takethe user into account when they design each attribute. • The different architects' experiences could affect the rejection of these attributes because the perception of the architect who has between 0-5 years' experience is different than that the architect who has more than 10 years' experience or between 5-10 years'. The fact is that usually the experience could affect the architects' knowledge such as on the necessity of considering user needs.
Conclusion	The following null hypotheses B_3, B_4 and B_5 were rejected.

Table 12-12: Research Question (9) The rejected hypothesis based on architect experience for the second part of the survey: B_3, B_4 and B_5 Results

12.1.6.3 Data reduction and clustering

Correlation methods as well as component methods were used to extract the variables. These methods extract the most effective EUFs and then group them together. EUFs analysis and the correlation coefficients matrix helped the researcher to cluster the EUFs that could be integrated as a list in each ATT in the proposed tool. The result was that 44 EUFs were extracted that were clustered in the six PDHAs. The clusters were used to create a simple sheet that was used to assess the design. The validity of these groups has been checked through reliability testing. This method shows that all the groups are valid, as shown in Chapter 11. This result is expected because all of them are essential and were selected based on a literature review. The classification has been used in the literature review and survey of this research. The six clusters' groups were based on the degree of significance as well as on the data reduction in the data analysis. The six clusters are PDF, PDP, PDU, PDFL, PDR and PDM. UCPBD assessment tool was compared with other assessment tools. It is distinguished by classification based on the six main ATTs compared to other assessment tools. There is no assessment tool that matches this classification, as well as there is no assessment tool that looks to the EUFs in relation to PD from these six ATTs. The justification of the six ATTs of the UCPBD assessment tool as follows:

Passive design Functionality

PDF is concentrated on the EUFs of this ATT. Various authors prompted the extracted EUFs as follows: AA3: Use nearby landforms and structures for wind protection and summer shading (Blocken, 2009), AB2: Use low mass construction to allow rapid heat-up or cooling of structure (The Concrete Centre, 2010), AB3: Shape the building to maximise exposure to [winter sun and summer breezes] (United States Department of Energy, 2000; Public Technology Inc. and US Green Building Council, 1996), AB4: Use high mass construction with appropriate insulation to promote night ventilation (Balasbaneh, 2010), AC1: Subdivide interior to create separate heating and cooling zones (Ministry for the Environment, 2008; Department of Education, Northern Ireland (DENI) and Corp Creator, 1998), AC2: Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible (City of Santa Barbara Community Development Department, 2006; United States Department of Energy, 2000), AC8: Consider interior surface colours and finishes for optimum day lighting (Li and Tsang, 2008), AC9: Design plan to create buffer zones from the summer radiation(Ip and Miller, 2006), AC10: Plan specific spaces or functions to coincide with solar orientation (Milne et al, 2008), AC11: Narrow floor width to optimise natural ventilation (Ministry for the Environment, 2008), AD2: Use skylight, light tube and clerestory for natural illumination (BIM, 2011), AE4: Use Trombe wall or double façade to collect solar gain (Awbi, 1998), AE6: Minimise openings in envelope to reduce thermal gain (United States Department of Energy, 2000), AE8: Develop details to minimise air infiltration and ex-filtration (Ministry for the Environment, 2008), AE10: Use louvred wall for maximum ventilation control (Gooch and Bickert, 1999). These EUFs can influence the success of the PDF ATT as well as delivering the design that meets EU needs.

Passive design Performance

The EUFs of this cluster are those found in relation to PDP. However, the researcher left the name of this cluster as it is because all the EUFs are related to this ATT. For this reason, the EUFs were grouped to be an independent cluster in UCPBD. The following EUFs: BB2: Select good colour to use (Dunne et al, 2011), BB6: Space layout enhances or interferes with well-being of occupants (Fowler et al, 2005; WBDG Productive Committee, 2011), BC1: The temperature controls provide for the needs of different occupants (Zachary et al, 2010; Thomas & Baird, 2006), BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants (Fowler et al, 2005; Gossauer and Wagner, 2007), BD1: A comfortable internal air temperature (Fowler et al, 2005; Gossauer and Wagner, 2007), BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast) (Fowler et al, 2005; Khalil and Husin, 2009), BE4: The lighting quality enhances or interferes with well-being of occupants (Fowler et al, 2005; WBDG Productive Committee, 2011) and BE5: Atrium or rotunda control devices for optimum space comfort (Khalil and Husin, 2009), are those stated in PDP. Applying these EUFs in UCPBD can lead to optimise L.V.T for improving indoor environment as well as meeting user satisfaction and reducing their complaints at the design stages.

Passive design Usability

The architects are aware that UCPBD is impossible without paying attention to usability and how it can be provided and suitable strategies considered at an early design stage. For this reason, this group is named based on this ATT as well as all the EUFs related to it. The following EUFs: CA1: Optimum position of service and passive element or equipment for operability (Lund, 2001), CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas) (Nylåna, 2005), CA3: Group homogeneous passive functions together for efficient operability (Nylåna, 2005; Jensø, 2011; Brown and Cole, 2009), CA4: Avoid slopes and steps of passive space floors (Mitchell, 2011), are listed under this group. The references to EUFs approve the effectiveness of these EUFs. It should be understood that there are other EUFs as well as what have been selected in this group. All of them lead to optimise L.V.T. as well as to maximise meeting EU needs during the early design stages.

Passive design Flexibility

The EUFs in this cluster are those concentrated on flexibility. This cluster is named flexibility because all its EUFs are related to PDFL. The EUFs are: DA3: Allow ample floor-to-floor height for future modification (City of New York, 1999; IBEC, 2008; Saari and Heikkilä, 2008), DA9: Design passive space to respond to changes in climate conditions (Slaughter, 2001), DB2: Design passive building to adapt for dysfunctional future utilisation (Till and Schneider, 2006), DB3: Allow ample floor-to-floor height for future modification (Moharram, 1980), DB4: Consider the passive design that accommodates fundamental changes in user preferences (Vakili-Ardebili and Boussabaine, 2006; Fernandez, 2003), DB5: Design the passive space to cope with changes in flow of users (Till, Jeremy and Schneider, Tatjana, 2006; Finch, 2009). These EUFs are referred to by different researchers. Considering the EUFs can influence the success of the design flexibility ATT with regard to its effectiveness for meeting EU needs. The EUFs are centred on providing strategies that can be flexible and adaptable to any changes. The EUFs of this group have been indicated by several researchers, as illustrated.

Passive design Reliability

The architects are aware that UCPBD is impossible without paying attention to reliability and how it can be provided, and considering its suitable strategies at an early design stage. For this reason, this group is named reliability because all the EUFs are related to this ATT. The following EUFs: EA2: Provide optimum drainage and venting to minimise accumulation of moisture (PERD, 1997), EA4: Select components that are resistant to environmental agents (ABCB, 2006), EB4: Use standardisation of passive design elements and materials (Wright and Frohnsdorff, 1985; ABCB, 2006; Balcomb, 1992; U.S. Department of Housing and Urban Development, 2002; Mital et al, 2007), are related to the PDR. These EUFs are referred to by different researchers, as shown before. Grouping the cluster under reliability is in order to optimise L.V.T elements to be able to handle any issues. If the designer considers theses strategies, the design can be classified as a reliable design.

Passive design Maintainability

Maintainability is the name of this cluster. The EUFs are concentrated on maintainability issues. The trends of the maintainability issue are that the building EU should be harmonised and be a clear target before any decision is made during the design process, in order to provide a building that is easy to maintain and repair as well as easy for the workers and the EUs to handle in the future. In this research 8 EUFs were introduced as the highest effective factors that should be taken into account when designing UCPBD. The 8 EUFs are: FA2: Simplify interface of passive design elements and building façade (NASA, 2008; Haiquan et al, 2011; Wani et al, 1999; Mohammed and Hassanain, 2010; Crow, 2002), FA6: Design for ease to remove or replace lighting, ventilation and thermal comfort elements (ARIS, 1995; Chew et al, 2004; NASA, 2008) and FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features (Northumberland National Park Authority, 2006), FC3: Access routes of passive space for transport of maintenance materials (NASA, 2008,13-5), FC4: Critical lighting, ventilation and thermal comfort element should be visible for inspection (Lin, 2010), FC5: All elements of the external passive building shell should be easy to access for maintenance and cleaning (Energy Saving Trust, 2006), FC6: Optimise sizes for passive design openings for workmanship access (NASA, 2008), FC7: Locate passive design elements where they are accessible for maintenance and repair (NASA, 2008: Crow, 2002). These EUFs are related to the PDM as well as being referred to by different researchers, as shown before. Grouping the cluster under maintainability is in order to optimise installation and selection of L.V.T elements during the design process to be able to handle any issues. By considering these strategies, the building design can be easy to maintain. It should be easy for both the actual Us and the maintenance workers to check the maintainability. The designer should consider maintainability for both current and future situations.

This tool is distinguished by considering the weighting of the EUFs by mathematical equation. In addition to that, the UCPBD assessment tool is developed based on interaction between PDS, PDHAs, U needs and architects' perspectives. Finally, it is simplified in a way to be easy to use and handle.

12.1.7 User Centred passive Building Design assessment tool

Research Question (11)

What is the most appreciate tool for integration EU needs into PBD design?

The majority of the design tools are concentrated on the environmental issues more than on EU needs. This model bridges the gap between them. PDHAs (Functionality, Performance, Usability, Flexibility, Reliability and Maintainability) are used and related to PD in order to improve its application when meeting EU needs. Paying attention to consideration of EU needs was looked at via various trends, as follows: the design process, through PDHAs, through considering various EU types, through assessment tool and through adaption of calculation methods. Application of the EUFs of the UCPBD tool will affect the PD as follows:

- Meeting EU needs can be enhanced through application of the UCPBD model and tool.

- Achieving PD in parallel with EU requirements.
- Maximising meeting EU needs and reducing their complaints before posting the design.
- Meeting EU needs will be through providing PD with PDHAs (Functionality, Performance, Usability, Flexibility, Reliability and Maintainability).
- Considering usability and flexibility will lead to enhancing meeting EU needs currently and in the future.
- Following the process of UCPBD can help the designer to ensure meeting EU needs for various ATTs.

The designers were asked to fill in the UCPBD form. The form included 44 EUFs, which included six clusters (see Appendix L). This form was developed based on the data reduction shown in Chapter 11. The EUFs are as listed in the previous sections. Then, the form was delivered to 4 architects who designed PBD. The designers were asked to score each EUF in case they implemented it or considered it when they designed the project. The projects which were tested are namely Houghton Street Project, Cherry Mill Project, Fitzroy Street Project and Tullis Russell Environmental Education (TREE) Centre. After these projects were scored by the designers, the scores of the EUFs were calculated based on two methods, which are design quality indicators and the proposed equation that considers designer scores with the weighting of each EUF. Developing two equations is done to show the results with and without weighting. The proposed methods prove the various levels of the test projects. This is an additional proof that the included EUFs are valid and essential in assessment of any PD. Also, it could help the designers to maximise the fulfilment of EU needs.

12.1.8 The Issues That Researcher Learened:

In this research, the researcher has investigated various design methods to find a way that can solve the problem of integrating user needs into passive design processes. One of the key points that have been learned from the systematic review is that the integration of user needs was cited in many references but it was sporadically discussed and never systematically addressed in a similar way as in IT design systems. This has inspired the author to try to find a way that emulates the processes used in IT systems in the design of passive buildings. From the outset this has posed an immense challenge to the author in terms of reconciling between terminologies and creating innovative end user concepts that are more appropriate to current building design practices. The author tackled this challenged through an iterative process of cross referencing between current building design practices and ISO standards on end user integration in IT systems development. The author cannot foresee any other ways of carrying out this task.

The second challenge posed by this research is how to bring together the initial results from the scoping study (literature) to develop a conceptual model. The author solved this issue through learning from the methods that already exists for developing conceptual models. Based on the study objectives, a phased approach was adopted, starting with simple flow charts, diagrams and moving through to more sophisticated numerical statistical analysis. The latter was necessary to iron out the inconsistencies, correlation and duplication in the model parameters, i.e. EUFs. This process is very generic to all conceptual model developments; if time was available the author could have spent time with designers to extract their views on the model before the survey was carried. However, this poses another challenge in the sense that most of the terminology will be unfamiliar to the designers' state of knowledge on end users factors.

The third challenge posed by the research was to find a credible sample of designers who have experience in passive design. The author used block emails to invite designers to complete the questionnaire. This method was found ineffective. The author then changed the strategy to an individual invitation to participation in a survey without sending the whole survey. If the respondents agree to participate, then the survey is sent to them. The methodology used to analyse the data from the survey is generic for this type of work. The main challenge was how to reduce the number of EUFs without losing the captured information. This was addressed appropriately through factor analysis. Other methods that could have been used for this purpose include component analysis. But this will require a large sample of data. The last challenge was which method can be used to develop the assessment tool. There were several methods that exist for this purpose, ranging from simple charts to more sophisticated Bayesian and artificial intelligence. The author opted for a simple method based on radar chart. This was necessary to increase the usability of the method. However, this could result in less accuracy then other more sophisticated methods.

12.1.9 Implication:

The UCPBD aimed to help the designers to ensure that PBD is high performance. This model was developed to manage both EU needs and environmental issues. It bridges the gap between EU needs and PDS by relying on the natural environment, and through investigation of the EU needs, process and design ATTs that could affect the PD. Implication could be affect in different fields which are namely in practice, cost, education, environment and research.

In terms of practice, the conceptual and the assessment tool could lead to enhancing and maximising the consideration of EU needs at various levels of design through considering EU needs through various ATTs. Using this model could lead to improving the performance of the design in current and future conditions. Also, the adaptability of this model for any changes and the flexibility of its expansion and contraction with EU needs is one of its advantages. These features of the design take into account the EU aspirations at unlimited horizon points. In addition to that, increasing the awareness of the designer about the classification of the EU in this research could lead to reduce EU complaints and could affect the concept and the form of any design.

In terms of the cost, considering the EU needs at various stages in the whole life cycle of PD could lead to reducing time and cost through potential future modifications. In addition to that, it could also reduce the cost in terms of modification or maintenance. When the task is easy to do or inspect, it will be different than the task when the design is complicated.

In terms of education, this will enhance the consideration of various issues during the training of the designers. Also, it could have an effect on the student mentality to look at the design from different perspectives in order to maximise the quality and the performance of the design for various types of user and for various conditions, whether at the current time or in the future. During data collection stage, AfterArora (2012), one of the respondents, had completed the questionnaire, he requested a copy of the survey for academic purposes, as shown in the following:

From: Sandeep SPA BHOPAL [sarora@spabhopal.ac.in]
Sent: 14 June 2012 08:29
To: Alzaed, Ali
Subject: Re: Please Ar Sandeep Arora

Dear Ali
The survey is done. I would like to receive a copy of results once your survey is done.
Also if its not an issue, I would like to have a copy of your questionnaire to be used as a sample for my students and only for academic purposes. I teach climate responsive archtiecture and related design studios at SPA.

thanks
Sandeep Arora
Assistant Prof.
School of Planning and Archtiecture
Bhopal, MP, India

This shows the accuracy and importance of the issues that the research has considered. Applying these trends could lead to the graduation of a new generation of architects who meet EU needs in parallel with ecological issues.

In terms of the environment, considering the PDS in parallel with EU needs can lead to enhancement of the indoor environment. Involving the strategies in the first ATT creates various choices and alternative solution that the designer could look at, in case one strategy cannot be installed or could be in conflict with the role of the other PDS. This model and assessment tool could enhance the designer's awareness during the design stages.

In terms of the research, this research is the starting point for wider horizons that still need to investigate the EUs' wishes in parallel with ecological conditions. There is still a lack of research on EU issues, and there is a need to investigate the EUs of different building types. Development of these EUFs in addition to the selected EUFs is also possible.

12.2 Conclusion and Recommendation

Despite an increasing interest in building performance assessment and sustainability evaluation, the results of such assessments do not take into consideration all EU needs. The majority of the study is concentrated on environmental and sustainable issues. In addition to that, the majority tended to concentrate on one or two aspects, such as post-occupancy evaluation, environmental issues, etc. The EU requirements have been involved during the design process as being central to the design process or stages. Some of the theories, such as post-occupancy evaluation, concentrate on EU needs after they have occupied the building, or ergonomic theory concentrates on EU comfort. However, EU needs are considered as EUFs, which are clustered into different groups. The UCPBD model tool is developed to fulfil EU needs. For this reason, the summary, contribution, limitation and recommendation for future study will be presented in this chapter.

12.2.1 Summary

To reduce EU complaints and match their requirements, EUFs of UCPBD ATTs should be considered in the design process. Architects claimed that they paid attention to EU needs during the PD process. The main concern usually is on environmental issues, functionality and aesthetics. Meeting EU needs was not a central part of the design process. Usually, the architects' practice EU needs based on their experience and put themselves in the EU's place. The importance of meeting EU needs as central to the PBD process leads to bridge them within UCPBD as a concept in parallel with other ATTs and design requirements. The design ATTs and their EUFs have been involved in UCPBD to enhance meeting EU needs. UCPBD concentrates on meeting EU needs through PDF, PDP, PDU, PDFL, PDR and PDM. Bridging the gap between EU needs and PDS was the main focus of this research. This research presents to what extent the EUFs can affect designing PD during the design process. One of the main aims of this research was to find a method that can match PDS with EU needs before developing the assessment tool that can help the designer to assess PDS. In this research, the model can be classified as an attempt to design a tool that creates an interaction between PDS and EU needs through the planning, design, development and operation of building assets. The areas that can be classified as pillars of this research are PDS, PDHAs and UCPBD process. The development of the model was through incorporating both PDS with EUFs through the design process. The UCPBD model is an assessment tool that helps the designer to assess the PD. Design quality indicators (DQI), existing assessment tools, the experience of the supervisor and brainstorming of the researcher were used to develop this model and to make it more practical, as well as using the weighting of EUFs to create the equation that could help the designer to assess the scores of the listed EUFs. This new approach can be classified as a multi-method approach, which is compiled based on a variety of sources, theories, case studies, author's personal knowledge, and architects' perceptions on PD, gained through their completion of the questionnaire.

12.2.2 Contribution

The main contribution of this research is to develop a conceptual model that can help the designers or architects to assess meeting EU needs in PD. The contribution can be classified into two groups, the main contributions to which are: EUFs of UCPBD and the new conceptual model contribution.

12.2.2.1 User factors

This research is developed based on a literature review of six design ATTs to highlight the EUFs for each ATT. The result was 132 EUFs. All of these EUFs were considered as the backbone of this research for both the literature review and survey in order to develop the conceptual model and an assessment tool. 132 EUFs were refined through data analysis stages to select the EUFs that could be included in the UCPBD assessment tool, which were a total of 44 EUFs. The contribution of this assessment tool is discussed in the following section.

12.2.2.2 UCPBD model

The conceptual model of the research comprises three main components: the dimensions of the PDS, the UCD process and the PDHAs. This model is distinguished by its contents and coherence. In addition to that, the design issues were considered in terms of process, and EU needs in relation to various ATTs. In addition to that, using a method of UCD design and implicating it in this model enhanced the research.

12.2.2.3 UCPBD frameworks

Sub-dividing the PDHAs of the UCPBD model into 22 S-ATTs made the research more comprehensive in terms of covering various trends of EU needs. In addition to that, involvement of the EUFs within each S-Att made the framework more coherent. In addition to that, this classification helped the researcher to design the questionnaire. The classification of the significant EUFs was achieved through data reduction.

12.2.2.4 UCPBD assessment tool contribution

The UCPBD tool is one of the innovations that helped the designer to assess the PBD. The tool is developed based on DQI and other methods, as shown in the discussion summary. Its benefits are as follows:

- The tool can help the designer to assess EU needs and L.V.T for UCPBD.
- This tool is easy to use because the score of the model is from 1 to 10, hence 1 is low implementation and consideration and 10 is high implementation and consideration.
- The tool can be updated through adding or removing EUFs based on the design requirement.

- The tool was developed based on DQI theories and simple mathematical techniques. In addition to that, it can also be assessed without weighting or with weighting that has been extracted based on the result of the data analysis.
- The extracted EUFs were selected through investigation of the critical literature review with all PDHAs as well as through the data reduction (see Chapter 10).
- The result can be shown in a graph for each case study, which shows the weakness and strength points of the design.

12.2.2.5 The other contributions

There are different contributions in this research besides UCPBD, as follows:

- Different definition based on the researcher perceptions, as follows: UCPBD. PDHAs, PDF, PDP, PDU, PDFL, PDR, PDM, EU experience, U.
- Extraction of EUFs based on the critical literature review (see Chapters 4).
- Ranked EUFs in PD (132 EUFs - see Chapter 8 rankings).
- 44 EUFs were the result of the data reduction used to develop UCPBD before clustering into 6 groups (see Chapter 10).
- This research fills the gap between EU needs and PDS through considering their needs at various ATTs. This research can help the designer to reduce complaints and meet EU needs through the design strategies, and deliver the building design with optimised lighting, ventilation and thermal comfort.
- The conceptual model was compared to the various design methods and architectural theories. The conceptual model, as far as the researcher knows, is the first attempt in the building industry.
- Classification of the U.
- UCPBD process which the designer should check each strategy or decision by going through each of the ATTs during the design process.

12.2.3 Limitations

Even though this conceptual model includes 132 EUFs, there are still some weaknesses that could improve the model:

1- This model was developed to be suitable for all building types. However, a model could be created for each building type such as school, office building, retail, etc.
2- The extracted EUFs are 132 EUFs, as appeared in this survey (see Appendix B). It could be there are some factors that are not involved in the survey.
3- The sample size of the questionnaire was from respondents with different experience and professional roles. This is shows only a part of the whole picture. It could be applied for a specific group, or country or experience to give it more authenticity.

4- Not enough suitable architects were one of the major challenges no.

The clustering of the the end user factors that limited to the same attributes of the proposed model. However, other researcher may cluster them in different clusters. This could leads to different result. In addition to that, selecting the strategies was based on the three main dimensions of passive design. Some of them could not be involved or used together. The reason is that the researcher extracted them is to cope with with the process of UCPBD in order to candidate different solutions then select the suitable one. However, other researcher could extract the strategies that could be worked together without any conflict. This could lead to reduce the number of EUFs or adding new factors.

12.2.4 Recommendation and Suggestions for Further Research

This research is focused on the EUFs that could help the designer to bridge the gap between EU needs and passive design. In addition to that, to what extend the extracted EUFs can have influence on passive building design. Further research could investigate more EUFs can help to improve or influence other design.

Further research on the model:

- Testing the model at various designs or case studies to investigate its weakness then improve it.
- Developing a model for each building type such as BREEAM assessment tool. BREEAM assessment tool classifies the building types as follows: Retail, Offices, Education, Prisons, Courts, Healthcare, Industrial, Specialised buildings assessed under the BREEAM Bespoke method, Multi-Residential, EcoHomes, Ecohomes XB, Higher Education, In use and Domestic Refurbishment (Jones, 2011).
- Developing each ATT through collection of more data and investigation.
- The model should be developed in a way that can be applied in various climates.
- The ATTs and S-ATTs reported in this work will be digitised to build a database that contains EUs' profiles. These profiles will be integrated with BIM processes. The EU information will be used by the designer along with BIM data in order to develop conceptual design solutions. Also, in the proposed UCPBD model the researcher foresees design ATTs being used as a benchmark for assessing the design solutions' compliance with EU needs.
- Other researchers could develop the conceptual model and assessment tool based on different countries and climates.

The checklist of the UCPBD can help the designer to meet EU needs and optimise the design for them. The achievement of this research, whether in terms of the tool, theory, or design process, is that, hopefully, the designer and researcher will consider them as starting points to widen horizons for fulfilling EU needs.

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Appendix A: Architectural Theories and Trends

Trend	Date	The Architects	Theories	Explanation	References
Post modernism	1955	James Stirling	From Garches to Jaoul : Le Corbusier as Domestic Architect in 1927 and 1953	*"By apparently repudiating his earlier work, Le Corbusier seemed to throw into question the entire programme of the rationalist and Functionalist Modernism. Yet, as Stirling and Gowan's Leicester Engineering Building (1964) demonstrates, the doubts led to a new kind of functionalism and used simple, industrial materials in a straightforward way. Stirling carried the notion of representation- the expression of function and symbolic forms"*(p.14) The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The functions and simplicity is related to the PDF and PDU.	(Jencks and Kropf ,2006)
	1960	Kevin Lynch	The Image of the City	*"His concern for the legibility of cities countered the abstract rationalism of Congress International Architecture Modern (CIAM) as well as the the unavoidable reality of suburban sprawl"*.p.18. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. This theory concentrates on Urban level.	(Jencks and Kropf ,2006)
	1961	N John Habraken	Supports : An Alternative to Mass Housing	*"Maintained the view that the built environment is a living thing and that change within a durable pattern is one of its its primary characteristics"*. p.22. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. This theory focus on the issues of Adaptability which the researcher considrrs them within PDFL.	(Jencks and Kropf ,2006)
	1965	Christopher Alexander	A city is not a tree	*"A city is not a Tree broke open and reoriented the debate. It also represented to a fundamental change. While retaining the mathematical foundation underlying his Notes on the synthesis of form, A city is not a tree takes it in a very different direction. Where the one takes seeks a crystalline logic to arrive at the notion of fitness between form and programme, the other points to a fundmnetal ambiguity and overlap in the realtion of form to its uses"*. p .30. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. This theory concentrates on the city issues and the form whichis part of PDF.	(Jencks and Kropf ,2006)
	1965	Christian Norberg-Schulz	Intentions in architecture	*"A reaction against modernism, in particular as realised after the war. Norberg-Schulz extended argument suggesting that the perception of form has a cultural basis and meaning in architecture is the result of cultural intentions. The task of the architect is then to work within the network of those intensions"*. p.33. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. This theory concentrates on the form which is take part of PDF.	(Jencks and Kropf ,2006)
	1966	Aldo Rossi	The Architecture of the city	*"Saw type more as subjective tool, as opposed to the objective view developed by Saverio Muratori and his followers]"*. p.37. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. This theory concentrates is not ralted the EU needs to PD..	(Jencks and Kropf ,2006)
	1966	Robert Venturi	Complexity and Contradiction in Architecture	*"A valid architecture evokes many levels of meaning and combinations of focus : its space and its elents become readable and workable in several ways at once"*. p.41. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. This theory concentrates on the PDU.	(Jencks and Kropf ,2006)
	1969	Charles Neck	Semiology and Architecture	*"Apart of a critique of modernism, he used of Semiology laid the foundation for the post-modernism"*.p43. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. This theory is mot related EU needs withing PD.	(Jencks and Kropf ,2006)

Trend	Date	The Architects	Theories	Explanation	References
Post modernism	1970	Giancarlo De Carlo	Architecture's public	*"Reacting against the reductive and authoritarian of modernism, he sought to initiate a broader design process that took account of a wider range of people and ideas"*. p.47. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1972	Charles Jencks and Nathan Silver	Adhocism	"*Exploits the arbitrary relation between signifier and signified, between form and function. It represents a further polemic against modernist purism and elitism but, compared to the extremes of pop, is a t once less consumed by technology and more pluralist"* .p.49. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1972	Robert Venturi, Denise Scott Brown and Steven Izenoure	Learning from Las Vegas	*"Taking the Las Vegas strip as an example, the authors argue for "ugly and ordinary" architecture and urbanism , and introduced the often quoted distinction between the "duck" and the "decorated shed"- between building as symbol and building with applied symbols"*.p.52. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1975	Charles Jencks	The rise of postmodern Architecture	*"Identify the preoccupations and range of specific antidotes that were emerging"*.p.57. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1975	Rob Krier	Urban space	*"It issues a direct attack against modernist urbanism as proposed by CIAM and its realisation in bastardised from after the second world war in the name of reconstruction, turns to the traditional city as a source for solutions to the problems of urbanism, countering the modernist isolated form in space with streets and squares defined by buildings"*.p.59. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1975	Colin Rowe and Fred Koetter	College City	*"By the 1960s and 70s, that fascination was helping to fill the theoretical vacuum left by the all too evident failures of modernist planning. Colin Rowe helped to codify the view, taking Rome as a paradigm for a new urbanism , both political and physical"*.p.61. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1975	Joseph Rykwert	Ornament is no Crime	*"On the importance of myth to building, the ways the classical orders carry meaning, and the idea of town"*. p.65. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1976	Aldo Rossi	An Analogical Architecture	*"The melancholic ambivalence towards modernism and the historic city so characteristic of those earlier writings is sustained in this essay"*.p.66. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1977	Kisho Kurokawa	Metabolism in Architecture	*"He was the most active in in further developing the ideas of metabolism.p.68. metabolism means The terminology is biological and it is related to architecture in terms of human society should be consider as a vital"*. . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

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Post modernism	1970	Kent C Bloomer and Charkes W Moore	Body, memory and Architecture	*"Taking expectation to the moralistic pretensions of modernism, responded with wit, learning and sensitivity to place. This essentially post-modern combination is demonstrated in both his writing and his buildings".p.71.* . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1978	Leon Krier	Rational Architecture : The reconstruction of the city	*"He recognised the exhibition rational architecture in London , bringing together the work of Italian , French , Belgian, and German Architects with a shared concern for the traditional city"*.p.75. . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1978	Anthony Vidler	The Third Typology	*"Provides what is perhaps the most incisive account of the ideas behind the " typo-morphological" approach to architecture as practised primarily by the Italians such as Also Rossi and Carlo Aymonino"*.p.77. . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1979	Christopher Alexander	The timeless way of Building	*"Method as well as a forceful repudiation of the reductive rationalism he had advocated in notes on the synthesis of form"*.p.80. . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1980	Dolores Hayden	What would a non- Sexiest city be like? Speculations on Housing, urban design, and human work.	*"Writing on the feminist and gender issues in architecture and urban design"*.p.84. . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1980	Charles Jencks	Towards a Radical Eclecticism	*"In the same way that the international style exhibition of 1932 at the new York museum of modern art helped crystallise the different strands of modernism into a recognised style, the presence of the past focused the concerns of post-modernism for a wider audience"*.p.86. . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1980	Paolo Portoghesi	The end of prohibitionism	"A clear development of his activities as architect and architectural historian, a combination not atypical in Italy. While the Italians have produced some of the most striking and convincing modernist architecture, they have, more than others lived with history". p.88. . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1980	Site	Notes of the philosophy of site	"To explore new possibilities for changing professional and popular response to the sociological ,psychological and aesthetic significance of architecture and public space".p.90. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1982	Michael Graves	A case for Figurative Architecture	*"Increasingly concerned with symbol , representation , history and myth"*. p.92. . The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1982	Oswald Mathias Ungers	Architecture as theme	*"Form is the expression of spiritual content"*.p.94. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

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Post modernism	1970	Kenneth Frampton	Towards a Critical Regionalism : six points for an architecture of resistance	*"The increasing importance of critical theory in the development of the post modernist debate"*.p.97. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1983	Lucien Kroll	The Architecture of complexity	*"He examines the way of achieving his aims within the constraints of an industrialized building process"*.p.101. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1984	MEMPHIS	The Memphis Idea	*"Draws a taut connection between sensuality and dissent"*.p.104. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1987	Kisho Kurokawa	The philosophy of Symbiosis	*"Draws in Buddhism , biology, and a characteristically Japanese view of technology as natural"*.p.106. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1989	Steven Holl	Anchoring	*"Concerned with both the metaphysical and phenomenological connection between architecture and its location"*p.109. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1991	Frank O Gehry	On his own house	*"Explored the strength and vitality of unfinished construction, using cheap materials in unconventional ways, notably in his own house"*.p.111. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1991	Itsuko Hasegawa	Architecture as another nature	*"Especially Japanese and metabolist view that sees human activity and technology as a part of nature"*.p.113. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1991	Eric Owen Moss	Which truth do you want to tell	*"Dismissive of the linear rationality implicit in modernism yet equally uninterested in architectural history and quotation, Moss rather seeks to puncture architectural preconceptions and extend the realms of the possible"*.p.115. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1993	Frank O Gehry	On the American centre , Paris An interview	*"Initiated the deconstructive movement"*. p.118. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1993	Jeffrey Kipnis	Towards a new Architecture: Folding	"On heterogeneity of the ideas rooted in the larger paradigm of complexity theory".p.121. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1993	Greg Lynn	Architectural Curvilinearity: The Folded , the pliant and the Supple	"Are characteristics of smooth transformation involving the intensive integration of differences within a continue yet heterogeneous system. Smooth mixtures are made up of disparate elements which maintain their integrity while being blended with a continue field of other free elements".p.125. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

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	1996	Arata Isozaki	The Island Nation Aesthetic	*"Critical of what he considered their reductive view of Modernism and in his own work made increasing use of electic architectural quotation both from Japanese and western Sources"*.p.128. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1996	Charles Jencks	13 proposition s of Post modern Architecture	*"This summary of the post modern movement"*. p.131. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Post Modern Ecology	1969	Ian McHarg	Design with nature	*"Combined a cogent set of general principles derived from the discipline of ecology with practical methods of design"*.p.134. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1979	Sim Van Der Ryn and Sterling Bunnell	Integral design	*"Involved with the Farallones Institute is setting up the integral urban house in west Berkeley , an experimental house intended to be as self-sufficient as possible in terms of energy , food and waste"*.p.136. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1984	Anne Whiston Spirn	The Granite Garden	*"Faces and explores the realited of sustaining vegetation in the urban environment in order to provide a basis for improving the quality of life in the city –not by erasing and replacing but complementing it"*.p.139. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1984	Nancy Jack Todd and John Todd	Bioshelters, Ocean Arks and City Farming: Ecology as the Basis of Design	*"Drawing on the work of Buckminster Fuller and Gregory Bateson, they have begun to establish both basic principles and specific technologies for ecological design.p.141"*. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1986	Hassan Fathy	Natural Energy and Vernacular Architecture	*"Shows the close connection Between the ecological approach , or at least a starnd within it, and vernacular"*.p.144. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1987	Kenneth Yeang	Tropical Urban Regionalism	*"In relating its attributes as a technological product to a particular place and time is as a vital connector that links technology with culture. The regionalist design approach seeks to articulate this linkage"*.p.146. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1990	Christopher Day	Places of the Soul	*"Concerned with both the human response to buildings and the effect of buildings on the environment"*.p.149. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1990	James Wines	Architect's statement	*"Makes more explicit arguments for green architecture as an antidote to the technological extremes of modernism and the theoretical extremes of deconstruction"*.p.152. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1991	Team Zoo/Atelier Zo	Principles of the design	*"The relation between the natural and cultural features of a place and the human response to them in the form of building"*.p.154. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

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Post Modern Ecology	1991	Brenda and Robert Vale	Green Architecture	*"Focus on low energy use, from the production of materials to thermodynamics of individual buildings, promoting a holistic approach to design"*. p.157. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1993	Peter Calthorpe	The Next American Metropolis	*"Introduced the isea of transit Oriented Developments , a concept developed further in the next America metropolis"*.p.161. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1994	Kenneth Yeang	Bioclimatic Skyscrapers	*"The high building in Bioclimatic Skyscrapers"*.p.164. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1996	Sim van Ser Ryn and Stuart Cowan	Ecological design	*"The fruit of a line of ecological thinking"*.p167. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Traditional	1969	Hassan Fathy	Architecture for the poor	*"Turned to traditional forms and methods of construction, seeking both to accommodate the needs of the community and to hint at a way to begin a revived tradition of building"*.p.170. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1976	Robert Maguire	The value of tradition	*"A satisfying structure hich enables us to get on and do things , where we have got to is kind of reversal of traditional modern-architectural attitudes by setting aside at the beginning intentions or ambitions about creating architecture"*.p.172. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1977	David Watkin	Morality and Architecture	*"Draws on Sir karl Popper's critique of historicism and traces, from AWN Pugin to Sir Nikolaus Pevsner , the essentially Ehig or operative version of architectural history that provided the moral imperative underpinning Modernism"*.p.174. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1978	The Brussels Declaration	Reconstruction of the European City	*"Promoting more or less anti-modernist architecture and urbanism based on historical and typological analysis"*.p.176. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1980	Maurice Culot	Reconstruction the city in stone	*"The use of traditional materials yet argue against capitalist means of production, combining what might be considered contrary positions"*.p.178. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1983	Demetri Porphyrios	Classicism is not a style	*"Achieves the classical balance of strengths and response with precision and clarity of purpose"*.p.179. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

Trend	Date	The Architects	Theories	Explanation	References
Traditional	1984	Leon krier	Building and Architecture	*"Focused increasingly on the importance of tradition"*. p.182. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1984	Robert Am Stern	On Style, Classicism and Pedagogy	*"Makes a more direct move toward Classicism , arguing for its timeless value as an architectural language and educational tool"*.p.183. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1984	HRH the prince of wales	RIBA Gala Speech	*"After praising the reaction against the modern movement and promoting the community architecture initiative, he launched the carbuncle salvo, drawing considerable return fire over the next few weeks both in the architectural and popular press"*.p.185. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1986	A;expander Tzonis and Liane Lefaiver	Critical Classism: the tragic Function	*"They coined the phrase critical regionalism, an idea later elaborated by Kenneth Frampton"*.p.186. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1987	HRH the prince of Wales	Mansion House Speech	*"Promoting community architecture , classism and conservation"*.p.189. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1989	Duany + Plater-Zyberk	Traditional neighbourhood development Ordinance	"*They combined Moore;s sense for American vernacular with the anti-Modernist urbanism of Leon Krier and European notions of typology. The result, as realised at seaside and later developments, is the traditional Neighbourhood Development (TND) based on a regulating plan and a set of building codes or ordiance"*.p.191. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1989	Quinlan Terry	Architecture and Theology	"A connection between religious faith and architectural style". p.193. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1989	HRH The Prince of Wales	A vision of Britian	*"A culmination of his architectural activism and in another a point of departure for further activity, the programme gave substance to the ideals hinted at in his previous speeches"*.p.196. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1992	The Urban Villages Groupe	Urban Villages	*"The goal of the group is to investigate and promote mixed-use and mixed-tenure development"*.p.199. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

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Traditional	1994	Allan Greenberg	Why classical architecture is modern	*"Inspired by the work of Sir Edwin Lutynes and others, he returned to classicism, exploring its possibilities through his many designs for courthouses"*.p.201. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Traditional	1994	Roger Scruton	Architectural principles in an age of Nihilism	*"Offers an aesthetic discipline of fundamental principles as an antidote to the nihilism, rather than a means for expressing it"*.p.203. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Late modern	1954	Philip Johnson	The seven Crutches of modern Architecture	*"Focusing more on the aesthetic –rather than the social-aspects of modernism"*.p.208. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Late modern	1955	Alison and Peter Smithson and Theo Crosby	The New Brutalism	*"An attempt to be objective about reality- the cultural objectives of society , its urges , its techniques and so on"*.p.211. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Late modern	1956	Paul Rudolph	The six determinants of architectural form	*"In this theory, it was classified six main point that should be consider when the designer thinking about the building form as follow: Environment of building, the functional aspect of the form, form particular region, climate, landscape, climate and natural lighting, form particular material which one uses, form is peculiar psychological demand of the space and finally form is concerned with the spirit of the times. The first and third one both of them is mentioned to the ecology. Regard the psychological of space and the activity how the space should be comfort and acceptable. Even though that, the user was not clear placed. There is also some user factors did not match with them. Our work was more comprehensive to meet it. p.213"*. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Late modern	1960	Reyner Banham	Theory and design in the first Machine age	*"Not so convinced by the architecture of the modern masters, much less their rhetoric, a position he makes clear in theory and design in the first machine age"*.p.216. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Late modern	1962	Cedric price	Activity and Change	*"Favours non-architectural solutions to the accommodation of human activities and denigrates the limitations of permanent and monumental buildings"*.p.217. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Late modern	1962	Alison and peter Smithson	Team 10 Primer	*"Sought a new way of seeing and new solutions to the problems of the contemporary city.p.218"*. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Late modern	1964	Christopher Alexander	Notes on the Synthesis of form	*"Fusing the disciplines , he applied a scientific rigour to the development of design methods. He sought to achieve a clear , rational design process free from the cultural preconceptions that cloud the view of the designer and lead to a lack of fitness between the form and its purpose.p.220."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

Trend	Date	The Architects	Theories	Explanation	References
Late Modern	1964	Archigram	Universal Structure	*"Contributing to the notion of mega structure, the images of these projects proved both compelling and disturbing and brought Archigram international attention.p.224".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1964	John Hejduk	Statement	*"Built relatively few buildings but through his projects , drawings and teaching has had an immense impact on American architecture.p.226".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1964	Fumihiko Maki	The Mega structure	The first to codify the notion of mega structure, an idea that was implicit in the work of the metabolist group and was emerging at the time in the work of architects as varied as Archigram and Paul Rudolph.p.227. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1966	Superstudio	Description of the Micro event / microenvironment	*"Used modern technology to question modern society. They extended the modernist notion of the emancipatory role of architecture and technology beyond the point at which architecture disappears.p.229".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1969	Reyner Banham	The Architecture of the well-tempered Environment	*"Takes up some of the preoccupations of theory and design in the first machine age , tracing the history of environmental control in architecture. P. 234."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1969	Louis I Kahn	Silence and Light	*"He extended the purism and structural logic of the first generation by turning the purity and logic into a question. p.236."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1969	Cedric Price	Non-Plan	*"Total dissolution of the planning system.p.239."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1972	Peter Eisenman	Cardboard architecture	*"Reveals a rational that repudiates functionalism.p.241."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1973	Manfredo Tafuri	Architecture and Utopia	*"Application of Marxist analysis to the production of buildings does, however, tend to result in a note of despair for the future.p.244."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1975	Philip Johnson	What makes me tick	*"Takes the form of a confessional , laying before the audience his fickleness yet his abiding concern for the formal and sensuous.p.246".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1975	Piano + Rogers	Statement	*"Belief in scientific enquiry as a tool both in its application to technology and as a more general paradigm for architectural expression.p.248".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

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Late modern	1976	Lionel March	The logic of design and the question of value	*"On the application of mathematics and analytical logic to architecture and urban design.p.250."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1985	Richard Rogers	Observation on architecture	*"Reconfirms his belief in functionalism, technology and scientific research as a foundation and tool for architecture. He also emphasises the idea that building form , plan section, and elevation should be capable of responding to changing needs, a capability sometimes frustrated by the exquisite sculptural – but static qualities of his buildings.p.252."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1990	Kenneth Frampton	Rappel alordre, the case for the tectonic	*"A means to get beyond the aprioristic of history and progress and outside the reactionary closures of historicism and the new-Avant-grade.p.254."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1991	Tadao Ando	Beyond Horizons in architecture	*"Without sentimentality, i aspire to transform place through architecture to the level of the abstract and the universal.p.256".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1994	Peter Rice	The role of the Engineer	*"Helped to stretch the realms of the possible, making fundamental contributions to the buildings on which he worked.p.259."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1994	Ian Ritchie	(Well) Connected Architecture	*"Ian determined six main criteria's. The first one is Art: this was classified to pre-concept and concept such as: transparency, solidity, minimalism, gravitas and lightness, and complexity. The next criteria is scientific and technology which includes materials, light and scientific understanding. The third criterion is the human purpose which involved reason, compliance and conflict. The next are functions are covered from follows desire and more from less. The fifth point is use and beauty which covered kind of use and aesthetic. The last point is authenticity architecture: this is for human purpose whether art, construction and science are. Even the enormous on these factors, the user centred passive building design theory differ from it, where our purpose is considered user needs as the main concern.p.261."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
New modern	1976	Peter Eisenman	Post functionalism	Appling the ideas of literary and critical theory, Eisenman extended his notion of an autonomous architecture, leading to a new modernism in which form is understood as a serious of fragments –signs without meaning dependent upon , and without reference to, a more basic condition.p.266. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1977	Bernard Tschumi	The pleasure of architecture –	He hints at at the pulsions motivating and unleashed by architecture.p.268. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1978	Coop Himmelblau	The future of splendid desolation	They have kindled a subversion of the autocrats whose motto is "efficiency, economy and expediency later stoked by their buildings.p.269. The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

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New modern	1978	Rem Koolhaas	Delirious New York: A retroactive manifesto for manhattan	*"A close examination of the dynamics that created the city of New York.p.271"* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1979	Daniel Libeskind	End Space	*"Carried out a fundamentally theoretical endeavour , using text and drawings to explore the tensions between experience, intuition and formalisation, the voluntary and the involuntary.p.274."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1980	Coope Himmelblau	Architecture Must Blaze	*"The blazing wing in the form of a steel frame suspended in the air incorporating flaming gas jets.p.276."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1981	Bernard Tschumi	The Manhattan Transcripts	*"Uses a tripartite mode of notion-events, movements, spaces as well as the notions of frame and sequence – as a means both to break down habitual and conventional readins of architecture and to suggest a new order of experience.p.277."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1982	Zaha Hadid	Randomness vs Arbitrariness	*"A comparison between Randomness and Arbitrariness.p.279."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1983	Zaha Hadid	The eighty nine degree	*"Makes clear her dedication to the programme of modernity and her equal determination to take it forward the future.p.280."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1983	Danial Libeskind	Unoriginal signs –	*"Uses juxtaposition, oxymoron and paradox as heuristic devices to reach beyond the limits of the verbal.p.281."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1984	Peter Eisenman	The end of classical , the end of beginning and the end of the end	*"A heated polemic against the classical and humanist paradigms in architecture. In their place he posits architecture as fiction, free from the weight of past or future.p.282."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1986	John Hejduck	Thoughts of an Architect	*"Investigates and plays on psychological associations resulting in a much more questioning form of architecture.p.285."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1988	Coop Himmelblau	The dissipation of our bodies in the city-	*"An account of its concern for and fascination with the contemporary city.p.286."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1988	Jeffrey Kipnis	Forms of irrationality	*"Applies a crystalline logic to a critique of rationality , seeking to identify and transcend the sources of resistance to innovation in the design process.p.288."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

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New modern	1988	Mark Wigley	Deconstructivist Architecture	*"While the deconstructivist exhibition did not have the same impact like modernism in the united states, it did raise the visibility of the style and its practitioners.p.291."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1991	Danial Libeskind	Upside Down X	*"A monograph on his work , Libeskind continues to search for something more than building.p.293."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1992	Danial Libeskind	Visions unfolding : architecture in the age electronic media	*"Explores in this essay the idea of endowing space with the possibility of looking back at subject , a space that cannot be put together in the traditional construct of vision.p.295."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1993	Will Alsop	Towards an Architecture of Practical Delight	*"Projected a vision of architectural that goes beyond its roots in the conceptual developments of modernism of the 50s and 60s.p.298."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1993	Thome Nayne	Connected Isolation	*"Their work is a fusion of complexity and diversity within an ordered framework, achieving a dynamic balance with the aim of reflecting the richness of our pluralistic world.p. 301."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1993	Lebbeus Woods	Manifesto	*"He seeks to go beyond the limits set by conventional knowledge and practice.p.304."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1994	Rem Koolhass	What ever Happen to Urbanism	*"Laments and exults in the conditions of contemporary architecture and urbanis.p.305."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1994	Rem Koolhass	Bigness or the problem of the large	*"Exposes a never that is intensive to style but has grown increasingly raw since the steel frame and lift were first brought together.p.307."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
Complexity	1977	Benoit B Maandelbrot-	The fractal Geometry of nature	*"Introduced the term fractal in 1975 in Les objects fractals , forme hazard et dimension but it was in the Fractal Geometry of Nature that Mandelbort more fully explored the aesthetic dimension of fractals.p.314."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1991	Howard Raggatt	Fringe Cringe	*"An attempts at a critical architecture based at the fringe.p.318".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1977	Michael Batty And Paul Longley	The fractal city	*"Demonstrates how more recent advances in mathematics such as the fractal as well as significantly increased computer power , GIS and more readily available data sets have made the models more compelling and more tractable.p.321."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

Trend	Date	The Architects	Theories	Explanation	References
	1999	Ben Van Berkel and Caroline Bos	Diagrams	*"The diagram serves as a tool for liberating architecture from language, interpretation and signification.p.325".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1999	Greg Lynn	Animate Form	*"Provides what is probably the most lucid and well-articulated exposition of the organisational modus , facilitated and generated by computers and computer software.p.328."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1999	MVRDV	Meta city/ Data Town	*"Conceived as a travelling exhibition that is an extension of office research and methods of absorbing and transforming the enormous amounts of data that are increasingly available and necessary for the design process. p.331."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	1999	Robert E Somol	Dummy Text , or the Diagrammatic Basis of contemporary architecture	*"Constructs dialectic between typology and neo-avant-garde self-organisation in the use of the diagrame.p.333."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2000	Forighen Office Architects	On Instruments: Diagrams, Drawing and Graphs	*"An essential element in the genesis of the design for the port terminal was the diagram or as set out in the text , the relationships between diagrams , drawings and graphs.p.337."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2000	West 8	Base, Colonisation, Void Totem Contemplation	*"Drawing on the deeply ingrained understanding , peculiar to the Dutch, of the landscape as a necessarily man-made phenomenon , West 8 happily dispense with any clear distinction between city and countryside.p.340."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2001	Steven – Johnson	Emergence	*"Weaves together a very clear and compelling picture of emergence as both a phenomenon and a way of thinking.p.343."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2001	Daniel Libeskind	The Space of Encounter	*"In this text , he excludes the singular catastrophe from consideration as a trauma on the basis that it can be overcome and healed , the running sore of the Twin Tower site might suggest otherwise.p.346".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2001	Lars Spuybroek	Machining Architecture	*"The diagram is intimately linked to the computer as a tool in the conceptual stages of design exemplified by the action-perception machines used in the masterclass.p.351.* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains."	(Jencks and Kropf ,2006)
	2002	Cecil Balmond	Informal	*"An investigation into the application of non-linear mathematics to engineer.p.353."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2002	Foreign office Architects	The Yokohama Project	*"A clear example of FOAs preoccupation with the manipulation of the ground and surface phenomena, it was also a means of exploring process of manipulation itself in terms of the means of implementation.p.354".* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

Trend	Date	The Architects	Theories	Explanation	References
Complexity	2002	Saskia Sassen	The Global city : introducing a concept and its history	*"Applies a clear analytical eye to the contemporary phenomena of the world economy.p.356."* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2002	Shop	Versioning	*"Promoting technique over image , in particular with the use of computers, play an issues of process and serial* The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.*ity.p.359."*	(Jencks and Kropf ,2006)
	2003	Stan Allen and James Corner	Urban natures	"Urbanism as primarily a matter of cultivation and management rather than the design of an object.p.361." The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2004	Zaha hadid	Explosions, compressions, swarms, aggregations, pixelations , carved spaces, excavations	"Her painted work both is formative of and provides a way into her constructed work both is formative of and provides a way into her constructed work. The interdependence of the two media is embodied in the multi-volume, multi-format complete works, from which this text is exceroted.p.364." The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2004	Charles Jencks	Towards an Iconography of the present	"Range in on the irony underlying the current desire for the certainties of iconic buildings in the context of the shifting heterogeneity of urban life.p.366" The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2004	Rem Koolhass	Junkspace	"An anti-mainfesto of responses to contemporary building practice, whether the product of nameless companies or star architects.p.370." The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2004	Michael Weinstock	Morphogenesis and the mathematics of emergence	"A hierarchy of levels at which emergence might be applied to architecture : in the design process within a computational environment , within a building with co-evolving distrusted systems, an within the urban environment with interaction buildings.p.373" The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)
	2005	Peter Eisenman	The Diagram as a Space of Difference : The MAK Exhibition: Excerpts from a Text	"Brings to the fore his longstanding preoccupations of presence and difference , writing and the diagram.p.376." The UCPBD theoritcal model concentrates on six main ATTs [PDF,PDP,PDU,PDFL,PDR and PDM]. Each one of them includes different EUFs. In addition to that, UCPBD includes a process that helps the design to EU needs in different ATTs. The UCPBD contains different than this theory contains.	(Jencks and Kropf ,2006)

Trend	Theories	Explanation	References
Sustainability	The green movement:	**Using clean energy efficiency is the main environmental concern. Sustainable development defined as** *"meets the needs of presents without compromising the ability of future generations to meet their own needs"p217. "The time has come to break out of past patterns. Attempts to maintain social and ecological stability through old approaches to development and environmental protection will increase instability. Security must be sought through change"*. In UCPBD model has been considered this theory as human factor that fulfil user needs. Our model is to meet user aspirating when applying passive design strategies.	Mallgrave and Goodman, D (2011)
	McDonough and Yeang	The issue of green is lead to formulate the designer task. Norman foster he designed 53 stories that touch several environmental issues. He considered lighting, ventilation and sky gardens to be centred of his design. He confirmed the sustainability idea through providing high tech. The landscape trend, in 1990, is moved from aesthetic to ecological. **McDonough referred to the sustainability notion should be more comprehensive more** than environmental damage. It is touched **human activity as well as their productivity**. McDonough in 1992, *"rights of humanity and nature to coexist". "Interdependence", "relationship between material and production and spiritual well-being. "the most effable of elements". "the most effable of elements"*.McDonough said ecological help the architect to be more creative one. He added the designer should be design product and its productive to physical context. In his design **consider light, water, garden, social interaction, orientation**. They focused on ecological issues. However, this approach is not related user needs as centred of design. In addition to that, it is integrated into passive design human attributes.	Mallgrave and Goodman, D (2011)
	Green urbanism	Consider future needs such as accessibility, ecological . Also, reducing stress, restorative effects of natural environment, considering people psychology for urban resodent. It also emhance urban vitality. Considering water, recycling, zero carbon emessions. Cobdsider air quality to avoid unhealthy air. This considers envirmental issues. However, it was concentrated on passive design or the rest attributes such as flexibility. In our work we propose UCPBD to fulfil user needs through various attributes.	Mallgrave and Goodman, D (2011)
	Biophilic design :	Julie Stewart-Pollack, ASID, IDEC (2006) defined this trend as *"Biophilic design recognizes the inherent human need for nature together with sustainable and universal design strategies to create environments that truly enhance life"*. This theory is referred to how people respond to environment. This is also considered psychological, physiological, neuroscience, health and well being of human. The landscape could lead to reduce stress, blood pressure and notable health. In the hospital room with view to landscape usually less complain. It is also concentrated on water, fresh air,sunlight,plants,views of nature, accessible green, architectural scale, proportions,materials and ornamentation. The different between our propose and this is the design process as well as the classification of passive design human attributes that used to integrate user needs through it.	Mallgrave and Goodman, D (2011)
	Neuroaesthetics:	This reflects on aesthetic judgment which is covered visual training, the human gender, meaning of objects, emotional variables, and culture and changing fashions. It is referred as *"human art behaviour"*. It is referred on traditional architecture as rhythm, scale, order visual complexity and ornamentation. The Varity on this approach are for aesthetic and environment. UCPBD considering theses variety in a way that match user needs.	Mallgrave and Goodman, D (2011)
Trends home	Earth-Friendly Home Design	This trend is emphasis the relationship between the home design and the environment how the design sensitive to it. This trend directs both architect and engineer to take a new look to the past building technique where it was using ecological material and simple technique. It was referred to the "earth houses" which covered three main aspects beauty, economical and comfortable. This trend is developed based on environment. In contrast, our UCPBD model is developed based on user needs.	Craven (2012)
	"Prefab" Home Design	Prefabricated hose design is inclined to direct the both engineer and architects to use modular material for both designer. The prefabricate design usually is bold design where it user still and glass. It is not limited on that this type of building can be in different shapes and styles whereas curves such as organic or streamlines form. In our propose model we considered the user needs to be the driver of the whole building factors on various attributes. This the clear differences between both approaches.	Craven (2012)
	Adaptive Reuse in Home Design	This trend is inclined to keep the environment as well as the historic through reuse or repurpose. This trend will lead to use the oldest material such as the shell of the outside of building. In our proposed model UCPBD the flexibility attribute is dealing with these issue	Craven (2012)
	Healthy Home Design	Healthy building as a trend is an attempt to design the building that is not affects our health. This trend because there is some design could make the user sick. This will be through using the material that could cause an effect on the user such as plastic, paint or glue. Considering material in our design is considered in some attributes. Also, considering the building that using natural lighting and natural ventilation elements are for pleasing the user and increasing their satisfaction.	Craven (2012)
	Storm-Resistant Home Design	Every shelter should be built to withstand the elements, and engineers are making steady progress in developing storm-ready home designs. In areas were hurricanes are prevalent, more and more builders are relying on insulated wall panels constructed of sturdy concrete. In our model, passive design reliability is for building to be able to resist face the natural hazard.	Craven (2012)

Trend	Theories	Explanation	References
Trends home	Flexible Floor Plans in Home Design	Changing lifestyles calls for changing living spaces. Tomorrow's homes have sliding doors, pocket doors, and other types of movable partitions allow flexibility in living arrangements. Dedicated living and dining rooms are being replaced by large multi-purpose family areas. In addition, many houses include private "bonus" rooms that can be used for office space or be adapted to a variety of specialized needs. This considers into passive design flexibility attributes to be integrated into the design based on user needs. There are also several attributes that involved in our propose model that help the designer to meet user needs which is differ from this theory.	Craven (2012)
	Accessible Home Design	This trend is for use ability whether they are able or disable they can move through the building. This kinds of home is comfortable to go through the design without any effort for all ages. In our propose model we considered these factors as part of usability.	Craven (2012)
	Outdoor Rooms in Home Design	This trend is to create the interaction between outside and inside the building such as connection with the landscape. Through providing the element that enhance that such as sliding glass, UCPBD model is included this interaction through link the building with site and landscape. However, our work is proposed to fulfil human needs through various attributes.	Craven (2012)
	Abundant Storage in Home Design	This trend is inclined to provide spaces for storages, providing storages is considered in our propose model as part of space planning element. However, our UCPBD model is considered various human factors which are provided to fulfil user needs. This is an obvious difference between them.	Craven (2012)
	Eastern Ideas in Home Design	This trend about how cans the designer borrowing or using design principles from other culture. it is specified eastern ideas which he thought can be affected on health and relationships. Using other principles could be contrast with culture or other existing principles. However, our work is considering matching human needs which are different from this propose.	Craven (2012)
	Dream houses:	This trend is about if the building meeting what we want or not. Also, it is related architecture to the self. This dreams is our main concern which we will try to fulfil through our propose model and through various attributes that involving several factors to reflect the user needs.	Craven (2012)
	Opposites in Architecture	This trend is about contrast in architecture. This is appears on mix materials or colours that are not harmony. In our proposed UCPBD model we consider user needs as the main concerns.	Craven (2012)
	What Is "Neo-Miesian"?	It is referred to Mies van der Rohe trend. It is raised in 20 century and he inclined to modernist. He uses the steel on glass as style for that period. In our model the style and material too place. However, the user needs is the main issue that demand to meet in our propose model.	Craven (2012)
	Colorful Buildings	It is one of the modernist trends which are focus on colour that needs to be considered such as using bright colour. However, this factors is part of using in passive design functionality in our propose model UCPBD model we considered user needs as main concern even in selection colour. There are various factors that are considered in our propose model. All of them to meet our main concern (match user needs).	Craven (2012)
Design approaches	System model	This method is work through understanding the system function. In addition, it could be through placing the system within the design context as well as replaced design components for function and motivations. In our approach (UCPBD) , we enhance the harmony between the building and user as well as the components. It is also considered the design function. However, this approach was cleared referred to the human needs or passive design strategies, which are the benchmarks of our work.	(Lidy ,2006)
	Environmental relations	This method is reflecting the relationship between the environment and human. In addition to that, during the design where the designer consider the interaction between material and environment. it reflects the placement of the building how can integrate the thermal strategies to optimise interior thermal. The rest of passive design strategies which has been involved on our theory were not involved in this theory. Also, in our model has been considered and integrated human needs.	(Lidy ,2006)
	Anthropometric Analogies	This method is concentrated on physical human and their size and how they integrate to the design. the user physical should be incorporate to solve the programme element. This is reflecting on the design spaces to be developed and completed. Such as providing space or bench or any element to be comfortable for usage. The human dimensions can be considered from various points such as on the floor, height or width. As shown in the following figure. in our UCPBD model has been integrated human factors at various attributes through various measurements. Physical user size were not referred to it.	(Lidy ,2006)
	Literal Analogies	This method is based on any existing form that can help to provide solution for the design. There are several projects. Brsilia airport is a good example where the designer form the airport based on the form of airplane. In our approach, building form has been concentrated as one of the sub-attribute of passive design functionality. Also, considering the existing form that can be enhanced the design functions has been considered on the site and orientation through considering benefit from surrounding building. The literal has been touched user needs or human factors and other UCPBD attributes.	(Lidy ,2006)
	Learning Probes	This method used through having a whole image of understanding the design issues. The design whole will create the issue and knowledge that need to understand and consider through interplay between the element. The best example of the when the designer needs to design house at the first stage cannot identify the best structure type or other. In this theory , the interaction between the design elements or the design and structure are the main concern . The end user needs was not take a place on this approach which is the centred of UCPBD model.	(Lidy ,2006)

Trend	Theories	Explanation	References
Design approaches	Subconscious Suggestion	This method means unintentional suggestion can be used to solve the design issues. Many authors not agree within method in order to it is unreliable. In my point of view this method is relying on imagination. In the following example, the roof structure takes the form strong yet thin from egg shell. In this method ,it is relied on inspiration to form the building or space. This is relying on the style. In terms of the passive design strategies or user needs was not placed clearly in this approach.	(Lidy ,2006)
	Brain storming	Group or collective effort is a centred of this method when they provide several solutions for the design. This could be in a process as shown in the following figure. This method is formed as a container of a design requirement. In our work , we considered the passive design and user needs as the main requirements. This is not involved as a clear demand on this approach. In terms of the solutions in our approach it is considered on the design process also on the alternative solutions.	(Lidy ,2006)
	Evaluation criteria	In this method will subordinates and criteria all other design elements to this criterion? Such as on the stage the last row should hear anything could happen on stage. In our approach , the evaluation is considered on the UCPBD model. In terms of its process has been considered after creation the solution. Also, passive design performance is an assessment that ensure the passive design functionality is performed as it is required. The user was not placed in this approach.	(Lidy ,2006)
	Well Spaced Alternatives	The designer should provide alternative solution for the spaces. This will be through providing or using various solutions. The various options will help the designer to find solution between them. in our model it has been considered through flexibility and passive design strategies. The user was not placed as a benchmark.	(Lidy ,2006)
	Means focus	In this method the designer plays with the form of building to generate solution for the design. This way will be instead of design problems. One of the methods used many sketches until achieved the stage. It is a idea that help the designer to create the design concept. until achieved the best form or concept. in UCPBD model considering form of building is considered as one of the passive design functionality sub-attributes.	(Lidy ,2006)
	Incremental improvement	Improve the design gradually is one of the techniques that the designer should use it. The case studies is helped to achieved that, where study the case studies then apply it on the new situation can help to make small improvement.	(Lidy ,2006)
	System model	This method is gives the ability for the designer to move the success design from somewhere to somewhere. In our theory, respected the identity is the closest meaning for this trend. This is not related to user needs which are our main concern.	(Lidy ,2006)
	Pattern languages	This method is part of creation interaction between user and environment. The patterns of various towns can be borrowed to apply somewhere else. In out theory, it is considered this trend as style or identity. It is referred in previous sections. Borrowing style does not mean fulfilling the usability or flexibility and others. This theory is focused on aesthetic to some extend.	(Lidy ,2006)
	Behavioural Setting	Identified pattern of the of user behaviour is one of the most important points which should the designer consider during the design process. For that, it's considered should be stable and independent. In my point of view, user behaviour is one of the limitations which can play a big role on success or fail the design. in our UCPBD model placed the human behaviour as one of the main criteria.	(Lidy ,2006)
	Structure-of-the-Problem	This method is concentrated on the key problem. For that when the main problem is solved or developed a solution for it. The design falls in this place. In the next photo the square is formed as the main problem should be address before completing the design. In our model UCPBD process is identified and solved the problem before delivering the final design. This is as an approach but there is no indicated about user or passive design strategies.	(Lidy ,2006)
	Disaggregation	This will be through divide the problem to many groups. The second stage will solve each one separately. Then, it will be solved before combing them all together before delivering the design. in our model is concentrated this idea for easy to separate and combine the design element together. Also it has been used three dimensions of passive design strategies.	(Lidy ,2006)
	Contemporary Architecture	This theory has been created during the last 30 years as well as developed during this period. The technologies revolution computers is affected on this period and create a unique style that was not created in the previous era. Contemporary theory is keep creating something new, even though the post modernism principles existing post modernist architecture. The three theories post modernism, modernism and contemporary are influence each other (Dudley,N/A). In terms of changeability, our propose model has been enhanced responses the design to the new technology or the future change through flexibility and usability attributes.	(About.com,2012)
	Structuralism	This theory is relied on the concept that everything is built from the signs. As a design process is reflected the **relationship between the elements**. It is not limited on that it is extend to cover **the mental process and social structures** into the design. This theory also covered the complexity to some extent. The complexity also is part of structuralism such as shapes. Cube grids . Peter Eisenman is one of the architects who was inclined to this trends (About.com,2012). In our propose model, the user needs is the main concern and the driver of the passive building design. In this theory, the passive design human attributes have not been touched.	(About.com,2012)
	Formalism	It is dealing with the building form as it is suggested on the name of the theory. It is express the relationship between the building form or shape and the rest of building parts (About.com,2012). This theory is concentrated on the form without referred to the human factors which are the main interest of user centred passive building design theory. There are various human factors which were integrated on passive building design.	(About.com,2012)

Trend	Theories	Explanation	References
Recent Design approaches	Usability measurements for building	The concept of usability is integrated on design building for human purpose. It is conducted through W111 Usability of workplaces. Blakstad (2010) referred to the usability as the building that support **user activities and physically surrounding** through contribution them with **efficiency, satisfaction and effectiveness**. The USETool has been determined as a tool to evaluate the usability of workplace. Before explain it. Usability could be a process as argue by Fenker (2008) and could **social construction**. It is defined as *"... given that they are designed for one or more activities, the artifacts are bearers of a set of possibilities and constraints as well as, most importantly, activity and social practices models."*. **The activities and social practice** of the user clarify the important on the usability. As it has been referred is designed for more than one activates. Blakstad (2010) said that the usability is covered three main point as follow, firstly, specified building users to achieve their needs. Secondly, the important of the building context this will lead to determine the dimensions of relationship between building and end users. Finally, efficiency user satisfaction and value creation contribute on the usability to achieve specified goal. These three points reflects to us the important of identify the user where they are visitor, **worker, residents their age and abilities**. The second point is the building type where the usability requirements for the school are not similar to usability on office building or residential building. Finally, meet user needs is the final stage in a way that satisfy. User needs could be considered without achieving high level of **satisfaction** such as providing function that are not suitable to user abilities. Blakstad (2010) related user experience to space design as one of usability determinants. For this reason, the spaces should be well function to be as they wish. This theory to some extend is focus on usability and it's important to integrate in building design. This theory is related to UCPBD as one of the six attributes. However, it is not related to passive design strategies. This theory is distinguished in order to considering human needs as well as their **satisfaction and activities**.	(Blakstad,2010), Fenker (2008)
	Post occupancy evaluation	The post occupancy evaluation as a theory considers the **user needs** through including **physical, technical and psychosocial aspects** and evaluations. POE is: *"... the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time"* Preiser et al. (1988) ac cited on Blakstad (2010). So this definition is reflected the important of user perception after using the building. This theory is an assessment for user after they occupied building. This is a difference between UCPBD where the later meet user needs during design process before delivering the final design.	Preiser et al. (1988) ac cited on Blakstad (2010).
	The use tool :	This tool is used to test usability. It has been integrated several methods. Define the evaluation is clarified if the building is increased its effectiveness. For this stage, interviews and documents studies are important. The second stage is mapping which will require studying the entire building. Entire building can cover several trends such as **adaptability, universal design, floor plan indoor climate and enhance functions** as shown in the table 1. The third stage is called walkthrough which is to gather user experience to be linked with criteria on stage 2. This will give an impression the reason behind success or fail of the function. The fourth stage is to study the attribution which could be affecting on the context of the building such as lighting, indoor climate, space availability. This will be considering through user perception. Finally, action plan. Drawing the plan this will be after the previous investigation and improve solution of the design.The USETool is also stress the important of considering user activates and needs, on the one hand. On the other hand, it is referred to interaction between space users and visitors. Also, the interior design such as accessibility, suitability and placement, the indoor environment requirement such as visual, air temperature and so on. In addition to that, the important of users dealing belongings and attraction. Finally enhancement the function by other requirement such as cleanliness, quick access and technologies. The USEtool is more comprehensive even with indoor environment. The use tool is accommodated the user needs. at various levels. However, its criteria's are involved under usability attribute. The rest of attributes of UCPBD is not referred as a clear attribute. The maintainability and flexibility was not taking a clear place on the USETool.	Blakstad (2010).
	Ergonomics and building design	The comfortable of user is becomes a clear demand that needs to be considered. Various approaches consider this issue. Ergonomics theory is a good example. Hedge (2008) referred to that ergonomic as part of environment that should be accommodated the end user **comfort, health and productivity**. LEED also referred to the important of having a comprehensive ergonomic strategy that promote user health and comfortable. USGBC (2008) indicated to the guidance for ergonomic design whether for current or expected design. It has been identified 4 steps as cited on Hedge (2008) which will be explained in the following section and summarised on the figure 3. -The first stage will be through identifying the function n and activities of the building in a way that enhance ergonomics. User preference should be involved and consider their possibilities to participate. - The second stage for characterisation a group of expectation and performance goals for enhance health, productivity and comfort for ergonomic strategy. Based on that the design process should be operated to meet them. -The third stage referred to some design features such as equipment, tools, work aids furnishing and machine and accessories to reduce the risk and be accepted for end users. -Last stage to provide ergonomic education for user. The designer should provide an opportunity for the end user to understand and take advantages of ergonomic features in their environment.	Hedge (2008). USGBC (2008)

Trend	Theories	Explanation	References
Recent Design approaches	Usability measurements for building	The concept of usability is integrated on design building for human purpose. It is conducted through W111 Usability of workplaces. Blakstad (2010) referred to the usability as the building that support **user activities and physically surrounding** through contribution them with **efficiency, satisfaction and effectiveness**. The USETool has been determined as a tool to evaluate the usability of workplace. Before explain it. Usability could be a process as argue by Fenker (2008) and could **social construction**. It is defined as *"... given that they are designed for one or more activities, the artifacts are bearers of a set of possibilities and constraints as well as, most importantly, activity and social practices models."*. **The activities and social practice** of the user clarify the important on the usability. As it has been referred is designed for more than one activates. Blakstad (2010) said that the usability is covered three main point as follow, firstly, specified building users to achieve their needs. Secondly, the important of the building context this will lead to determine the dimensions of relationship between building and end users. Finally, efficiency user satisfaction and value creation contribute on the usability to achieve specified goal. These three points reflects to us the important of identify the user where they are visitor, **worker, residents their age and abilities**. The second point is the building type where the usability requirements for the school are not similar to usability on office building or residential building. Finally, meet user needs is the final stage in a way that satisfy. User needs could be considered without achieving high level of **satisfaction** such as providing function that are not suitable to user abilities. Blakstad (2010) related user experience to space design as one of usability determinants. For this reason, the spaces should be well function to be as they wish. This theory to some extend is focus on usability and it's important to integrate in building design. This theory is related to UCPBD as one of the six attributes. However, it is not related to passive design strategies. This theory is distinguished in order to considering human needs as well as their **satisfaction and activities**.	(Blakstad,2010), Fenker (2008)
	Post occupancy evaluation	The post occupancy evaluation as a theory considers the **user needs** through including **physical, technical and psychosocial aspects** and evaluations. POE is: *"... the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time"* Preiser et al. (1988) ac cited on Blakstad (2010). So this definition is reflected the important of user perception after using the building. This theory is an assessment for user after they occupied building. This is a difference between UCPBD where the later meet user needs during design process before delivering the final design.	Preiser et al. (1988) ac cited on Blakstad (2010).
	The use tool :	This tool is used to test usability. It has been integrated several methods. Define the evaluation is clarified if the building is increased its effectiveness. For this stage, interviews and documents studies are important. The second stage is mapping which will require studying the entire building. Entire building can cover several trends such as **adaptability, universal design, floor plan indoor climate and enhance functions** as shown in the table 1. The third stage is called walkthrough which is to gather user experience to be linked with criteria on stage 2. This will give an impression the reason behind success or fail of the function. The fourth stage is to study the attribution which could be affecting on the context of the building such as lighting, indoor climate, space availability. This will be considering through user perception. Finally, action plan. Drawing the plan this will be after the previous investigation and improve solution of the design.The USETool is also stress the important of considering user activates and needs, on the one hand. On the other hand, it is referred to interaction between space users and visitors. Also, the interior design such as accessibility, suitability and placement, the indoor environment requirement such as visual, air temperature and so on. In addition to that, the important of users dealing belongings and attraction. Finally enhancement the function by other requirement such as cleanliness, quick access and technologies. The USEtool is more comprehensive even with indoor environment. The use tool is accommodated the user needs. at various levels. However, its criteria's are involved under usability attribute. The rest of attributes of UCPBD is not referred as a clear attribute. The maintainability and flexibility was not taking a clear place on the USETool.	Blakstad (2010).
	Ergonomics and building design	The comfortable of user is becomes a clear demand that needs to be considered. Various approaches consider this issue. Ergonomics theory is a good example. Hedge (2008) referred to that ergonomic as part of environment that should be accommodated the end user **comfort, health and productivity**. LEED also referred to the important of having a comprehensive ergonomic strategy that promote user health and comfortable. USGBC (2008) indicated to the guidance for ergonomic design whether for current or expected design. It has been identified 4 steps as cited on Hedge (2008) which will be explained in the following section and summarised on the figure 3. -The first stage will be through identifying the function n and activities of the building in a way that enhance ergonomics. User preference should be involved and consider their possibilities to participate. - The second stage for characterisation a group of expectation and performance goals for enhance health, productivity and comfort for ergonomic strategy. Based on that the design process should be operated to meet them. -The third stage referred to some design features such as equipment, tools, work aids furnishing and machine and accessories to reduce the risk and be accepted for end users. -Last stage to provide ergonomic education for user. The designer should provide an opportunity for the end user to understand and take advantages of ergonomic features in their environment.	Hedge (2008). USGBC (2008)

Appendix B – Questionnaire

USER CENTERED PASSIVE BUILDING DESIGN

(UCPBD)

Questionnaire

By

ALI ALZAED

Under supervision

Dr Halim Boussabaine

The University of Liverpool - School of Architecture

User-Centred Passive Building Design Determinants

Introduction:

You are being invited to participate in an online survey to investigate human factors in passive building design. There are no foreseeable risks or adverse events to you from taking part in this study. Participation is voluntary; however we would very much value your views. It should only take between 15-20 minutes of your time. Before you decide whether to participate, please read the following information carefully.

Technology Strategy Board (TSB) has recognised the importance of user-centred design in all aspects of building procurement processes - "more expertise in human factors research and user-centred design is needed in engineering consultancies, product manufacturers, building designers, facilities management companies and others". The user-centred design approach considers the user's needs in a way that can lead to shaping the design from both technical and socio-economic perspectives. To ensure that the appropriate human factors are selected and integrated into design we need to understand what are the most relevant human factors and how to integrate them into various passive design strategies. We are addressing this emerging design paradigm through the development of a systematic user-centred passive building design approach (a design approach that places both user and passive design strategies at the centre of the design process for focusing architects' minds on users through the planning, design, development and operation of building assets). The results from this research will demonstrate and advance our knowledge in the area of passive building design by integrating user human factors into the design process. Hopefully if this can be achieved then it will certainly lead to the design of highly-performing and resilient buildings. Thus, the purpose of this survey is to assess the effectiveness of the user factors in passive design processes.

All individual responses will remain confidential and study data will be amalgamated and analysed as a whole. Results will be reported in summary form to protect confidentiality. However, if you have any questions or concerns about the questionnaire or about participating in this research, you may contact me on 07403 055503 or at A.Alzaed@liv.ac.uk. Or alternatively you may communicate concerns to the Research Governance Officer on 0151 794 8290 (ethics@liv.ac.uk) quoting the research title and the details of the concerns you have.

Thank you for your time and support, and I look forward to sharing the outcomes of this survey with all of the participants.

Please also feel free to forward this survey to architects who practise in the UK only.

Yours sincerely

Ali Alzaed
PhD Candidate
School of Architecture
The University of Liverpool
Mobile: 07403055503
e-mail: A.Alzaed@liv.ac.uk

The research is directed by:
Dr H Boussabaine
School of Architecture
The University of Liverpool
Tel: 0151 794 2619

Participant's consent

1- Do you wish to participate in this study?

By clicking YES you acknowledge that you have given consent to participate in this study. I understand that my participation is voluntary and that I can discontinue the completion of the questionnaire at any time by clicking CANCEL. This is an anonymous survey; it is not possible to withdraw your answers once you have clicked the DONE button.

Yes		No	

User-Centred Passive Design: Functionality

1- How effective are the following site, orientation and vegetation design factors in improving user experience in passive building design?

Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
AA1	Use vegetation for optimum lighting, ventilation and thermal comfort					
AA2	Orient the building for optimum lighting, ventilation and thermal comfort					
AA3	Use nearby landforms and structures for wind protection and summer shading					

2- How effective are the following building form design factors in improving user experience in passive building design?

Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
AB1	Design compact building form for optimum heating and ventilation					
AB2	Use low mass construction to allow rapid heat-up or cooling of structure					
AB3	Shape the building to maximise exposure to [winter sun and summer breezes]					
AB4	Use high mass construction with appropriate insulation to promote night ventilation					

3- How effective are the following space planning design factors in improving user experience in passive building design?

Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
AC1	Subdivide interior to create separate heating and cooling zones					
AC2	Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible					
AC3	Use central atriums, courtyards and lobbies (elevators, and stairs can be locate in central areas) for optimum ventilation					
AC4	Provide vertical air shafts/stacks, and central exhaust paths to promote interior airflow					
AC5	Use open plan interior to promote interior airflow					
AC6	The proportion of the plan is long and narrow (use linear plan form, or a similar strategy) to optimise day lighting					
AC7	Orgnise rooms, corridors, stairwells in a way that uploads a low resistance airflow path through the building					
AC8	Consider interior surface colours and finishes for optimum day lighting					
AC9	Design plan to create buffer zones from the summer radiation					

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
AC10	Plan specific spaces or functions to coincide with solar orientation					
AC11	Narrow floor width to optimise natural ventilation					
AC12	Provide solar-oriented interior zone to store and maximise solar heat gain					
AC13	Attenuate plan to promote ventilation					
AC14	Link the exterior and interior airflows by single-sided, cross or stack ventilation					

4- How effective are the following roof design factors in improving user experience in passive building design?

Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
AD1	Use roof elements for stack effect ventilation					
AD2	Use skylight, light tube and clerestory for natural illumination					
AD3	Use solar roof collectors on the south-oriented surfaces					
AD4	Use double roof and wall construction for ventilation within envelope					
AD5	Use ventilated roof to lower summer gains through roof					
AD6	Use of an appropriate shape and angle of the roof for optimum ventilation and thermal comfort					

5- How effective are the following facade and envelope design factors in improving user experience in passive building design?

Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
AE1	Minimise the ratio of exterior surfaces to interior floor areas					
AE2	Use high-capacitance materials to store solar heat gain and control heat flow through envelope					
AE3	Optimise south-facing glazing					
AE4	Use Trombe wall or double façade to collect solar gain					
AE5	Locate thermal mass inside the envelope to store heating					
AE6	Minimise openings in envelope to reduce thermal gain					
AE7	Use solar wall on south-oriented surfaces					
AE8	Develop details to minimise air infiltration and exfiltration					
AE9	Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort					
AE10	Use louvred wall for maximum ventilation control					
AE11	Use exterior elements to direct summer wind flow into the interior					
AE12	Orient openings to facilitate natural ventilation					
AE13	Details openings to limit undesired air infiltration and exfiltration as well as to reduce convective gains					
AE14	Provide light shelves to allow daylight to penetrate deep into a building					
AE15	Use higher window to wall area ratios to maximise solar access and ventilation					
AE16	Provide high levels of insulation in the facade and building envelope to reduce summer conductive gain and to preserve internal heat					

User-Centred Passive Design: Performance

6- How effective are the following site performance design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
BA1	Utilising views and orientation					
BA2	Affect site on visual focus					
BA3	Enhancement of site to consider identity					

7- How effective are the following space performance design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
BB1	Durable, high quality finishes					
BB2	Select good colour to use					
BB3	Passive spaces layout allow social interaction					
BB4	Provide a special character for the space based on building type					
BB5	Space layout allows for security, way finding, and flexibility of use					
BB6	Space layout enhances or interferes with wellbeing of occupants					
BB7	The adequacy of passive design space available for function/activities					

8- How effective are the following thermal comfort design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
BC1	The temperature controls provide for the needs of different occupants					
BC2	Thermal comfort in spaces enhances or interferes with wellbeing of occupants					

9- How effective are the following natural ventilation design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
BD1	A comfortable internal air temperature					
BD2	The air quality in space enhances or interferes with wellbeing of occupants					
BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)					

10- How effective are the following lighting design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
BE1	The adequacy of light sufficiency in spaces					
BE2	The adequacy of natural light in spaces					
BE3	The visual comfort of the lighting (e.g., glare, reflections, contrast)					
BE4	The lighting quality enhances or interferes with wellbeing of occupants					
BE5	Atrium or rotunda control devices for optimum space comfort					

11- How effective are the following acoustic design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
BF1	Select insulation against noises from corridors to give space privacy					
BF2	Utilise good acoustic conditions					

12- How effective are the following adequacy consumption and strategies design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
BG1	The horizontal utility systems of passive building logically configured to serve multi-user needs					
BG2	Utility passive design cores uniformly designed and vertically stacked					
BG3	Make the atrium or rotunda adequate for cleaning, maintenance etc					
BG4	Reduce consumption of water, energy and electricity					
BG5	Response time to urgent repair issues					

User-Centred Passive Design: Usability

13- How effective are the following operability design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
CA1	Optimum position of service and passive element or equipment for operability					
CA2	Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)					
CA3	Group homogeneous passive functions together for efficient operability					
CA4	Avoid slopes and steps of passive space floors					
CA5	Incorporate passive design technologies which are easy to operate by multiple users					
CA6	Accessible passive design controls for multiple users					
CA7	Design passive space that is well-suited for multi-user activities and capabilities					
CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)					

14- How effective are the following human behaviour design factors in improving user experience in passive building design? Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
CB1	Reduce user stress and feelings of frustration due to lack of space					
CB2	Consider safety, health and physical wellbeing needs for multiple users of passive buildings					
CB3	Consider different sensing, smelling, hearing, feeling and seeing of users in passive space design					
CB4	Consider users' cultural image, identity, lifestyle, psychological needs and perceptions in line with passive lighting, ventilation and thermal comfort strategies					

User-Centred Passive Design: Flexibility

15- How effective are the following future adaptability design factors in improving user experience in passive building design? Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
DA1	Passive building structure should be upgradable for future regulations and safety procedures					
DA2	Design passive building to adapt for dysfunctional future utilisation					
DA3	Allow ample floor-to-floor height for future modification					
DA4	Consider the passive design that accommodates fundamental changes in user preferences					
DA5	Design the passive space to cope with changes in flow of users					
DA6	Provide horizontal and vertical circulation and spaces of passive design that encompass future expansion options					
DA7	Design a passive building that responds to the increasing pressures of rapid changes in technology shifts					
DA8	Design passive space that responds to changes in spatial dimensions (volume)					
DA9	Design passive space to respond to changes in climate conditions					
DA10	Design passive layout based on future use scenarios					
DA11	Select the passive building form for change without changing the skeleton					

16- How effective are the following flexible space design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
DB1	Specify spaces for multiple use					
DB2	Use movable walls					
DB3	Flexible access within and between passive spaces					
DB4	The ability to subdivide large passive design spaces					
DB5	Use modular passive space planning strategies					
DB6	Minimise partitions between passive spaces to control lighting, ventilation and thermal comfort					
DB7	Design passive space to incorporate completely new functions					

User-Centred Passive Design: Reliability

17- How effective are the following durability design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
EA1	Ensure the passive performance of space or element remains serviceable					
EA2	Provide optimum drainage and venting to minimise accumulation of moisture					
EA3	Design passive service life to match user needs					
EA4	Select components that are resistant to environmental agents					
EA5	Compatibility in joining lighting, ventilation and thermal comfort elements together					
EA6	Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation					
EA7	Protect sensitive passive elements from accidental change					

18- How effective are the following material reliability design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
EB1	Consider passive building joint seals to resist infiltration of moisture or deleterious materials					
EB2	Use high quality material with long service life to handle passive functions					
EB3	Consider the rate of expansion / contraction of material of passive design strategies					
EB4	Use standardisation of passive design elements and materials					

19- How effective are the following resilient design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
EC1	Specify passive space strategies for user behaviour usage (such as heavy use, accidental impact and interior humidity)					
EC2	Passive building fabric should be adaptable to cyclic change					

User-Centred Passive Design: Maintainability

20- How effective are the following standardisation design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
FA1	Provide lighting and ventilation in expected maintenance areas					
FA2	Simplify interface of passive design elements and building facade					
FA3	Specify simple shape of both building form and space of passive design					
FA4	Utilise non-destructive disassembly passive design strategies					
FA5	Eliminate poor detailing of passive design space or element					
FA6	Design for ease to remove or replace lighting, ventilation and thermal comfort elements					
FA7	Design for ease to adjust lighting, ventilation and thermal comfort physical element features					
FA8	Design for ease of installing lighting, ventilation and thermal comfort element or material					
FA9	Provide passive design strategies that minimise the time for maintenance					

21- How effective are the following material design factors in improving user experience in passive building design?
Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
FB1	Minimise use of unique materials of passive design strategies					
FB2	Locate lighting, ventilation and thermal comfort materials for operability to minimise degradation					
FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity					

22- How effective are the following accessibility design factors in improving user experience in passive building design?

Please check one box

Code	End User Factors	Very Ineffective	Ineffective	Neutral	Effective	Very Effective
FC1	The cleanliness and maintenance of passive spaces enhances or interferes with wellbeing of occupants					
FC2	The interior of the passive building is designed to be easy to clean and maintain					
FC3	Access routes of passive space for transport of maintenance materials					
FC4	Critical lighting, ventilation and thermal comfort element should be visible for inspection					
FC5	All elements of the external passive building shell should be easy to access for maintenance and cleaning					
FC6	Optimise sizes for passive design openings for workmanship access					
FC7	Locate passive design elements where they are accessible for maintenance and repair					

Current Practices:

Passive Design Functionality: [A set of design determinants that relate to the existence of a set of passive design functions (i.e. ventilation, lighting and heating) that fulfil user needs].

How often do you keep end user needs in your mind in relation to passive lighting, ventilation and heating when you specify passive design functionality?

Code	Never	Sometimes	Always
GA			

Passive Design Performance: [A set of determinants that measure passive design functions under stated user conditions].

How often do you keep end user needs in your mind in relation to passive lighting, ventilation and heating when you specify passive design performance?

Code	Never	Sometimes	Always
GB			

Passive Design Usability: [A set of attributes that relate to operability and compliance of passive design strategies to regulation standards and user operational efficiency].

How often do you keep end user needs in your mind in relation to passive lighting, ventilation and heating when you specify passive design usability?

Code	Never	Sometimes	Always
GC			

Passive Design Flexibility: [A set of attributes that relate the ability of passive design strategies to be remodelled to satisfy new use conditions].

How often do you keep end user needs in your mind in relation to passive lighting, ventilation and heating when you specify passive design flexibility?

Code	Never	Sometimes	Always
GD			

Passive Design Reliability: [A set of determinants that relate to the capability of passive design functions to maintain their level of performance under user stated conditions within the design service life period].

How often do you keep end user needs in your mind in relation to passive lighting, ventilation and heating when you specify passive design reliability?

Code	Never	Sometimes	Always
GG			

Passive Design Maintainability: [A set of determinants that relate to the ease of inspecting, maintaining and modifying design to satisfy evolving user needs].

How often do you keep end user needs in your mind in relation to passive lighting, ventilation and heating when you specify passive design maintainability?

Code	Never	Sometimes	Always
GF			

Personal information:

1-	Respondent's name (optional)	
2-	Contacts details if you wish to enter into prize draw for an iPad2 16GB (optional)	Email : Contact number:
3-	Company name (optional)	
L	What is your professional role? - ☐ Architect practicing ☐ - Academic and Architect practicing ☐ - Academic	
M	How many years of experience do you have? - ☐ 0-5 Years ☐ - 5-10 Years ☐ - More than 10 years	
N	If you wish to receive a summary of our results upon completion of our study then please supply your name and contact email? - Yes [Contact details] - No	

You have completed the survey. Please Click on DONE to submit the survey Thank you for your participation

Appendix C – ETHICAL APPROVAL APPLICATION

From: Fletcher, Sarah on behalf of Ethics
Sent: 30 March 2012 09:47
To: Boussabaine, Halim; Ethics
Cc: Alzaed, Ali
Subject: RE: RETH000532

Dear Dr Boussabaine

I am pleased to inform you that the Sub-Committee has approved your application for ethical approval. Details and conditions of the approval can be found below.

In order that this approval is valid, please ensure that you send a signed copy of the final version, with all supporting documentation, to the Research Governance Officer, Legal, Risk and Compliance, 2nd Floor Block C, Waterhouse Buildings, Liverpool, L69 3GL within 5 days of receipt of this email.

Ref:	RETH000532
Sub-Committee:	Non-Invasive Procedures
PI:	Dr Halim Boussabaine
Title:	User-centred passive building design determinantes
First Reviewer:	Dr Francine Watkins
Second Reviewer:	Dr Carl Hopkins
Third Reviewer (if applicable):	n/a
Date of initial review:	30/3/12
Date of Approval:	30/3/12

The application was APPROVED subject to the following conditions:

Conditions

1	Mandatory	M: All serious adverse events must be reported to the Sub-Committee within 24 hours of their occurrence, via the Research Governance Officer (ethics@liv.ac.uk).

This approval applies for the duration of the research. If it is proposed to extend the duration of the study as specified in the application form, the Sub-Committee should be notified. If it is proposed to make an amendment to the research, you should notify the Sub-Committee by following the Notice of Amendment procedure outlined at http://www.liv.ac.uk/researchethics/amendment%20procedure%209-08.doc. If the named PI / Supervisor leaves the employment of the University during the course of this approval, the approval will lapse. Therefore please contact the RGO at ethics@liverpool.ac.uk in order to notify them of a change in PI / Supervisor.

Best Wishes
Sarah

Appendix D – Passive Design Functionality Histogram and Frequency Table

Table D1: Histogram and Frequency of Passive Design Functionality

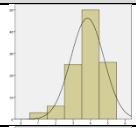
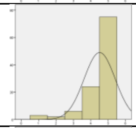
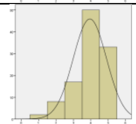
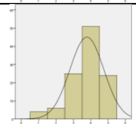
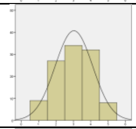
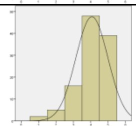
Code	End User factors of Passive Design Functionality	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
AA1	Use vegetation for optimum lighting, ventilation and thermal comfort	110	2.7	5.5	22.7	45.5	23.6	3	6	25	50	26	3.82	.950	
AA2	Orient the building for optimum lighting, ventilation and thermal comfort	110	2.7	1.8	5.5	21.8	68.2	3	2	6	24	75	4.51	.896	
AA3	Use nearby landforms and structures for wind protection and summer shading	110	1.8	7.3	15.5	45.5	30.0	2	8	17	50	33	3.95	.956	
AB1	Design compact building form for optimum heating and ventilation	110	3.6	5.5	22.7	46.4	21.8	4	6	25	51	24	3.77	.974	
AB2	Use low mass construction to allow rapid heat-up or cooling of structure	110	8.2	24.5	30.9	29.1	7.3	9	27	34	32	8	3.03	1.079	
AB3	Shape the building to maximise exposure to [winter sun and summer breezes]	110	1.8	4.5	14.5	43.6	35.5	2	5	16	48	39	4.06	.921	

Table D2: Histogram and Frequency of Passive Design Functionality

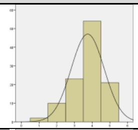
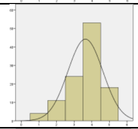
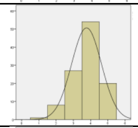
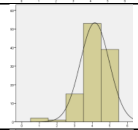
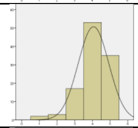
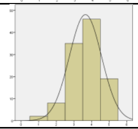
Code	End User factors of Passive Design Functionality	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
AB4	Use high mass construction with appropriate insulation to promote night ventilation	110	1.8	9.1	20.9	49.1	19.1	2	10	23	54	21	3.75	.933	
AC1	Subdivide interior to create separate heating and cooling zones	110	3.6	10.0	21.8	48.2	16.4	4	11	24	53	18	3.64	.993	
AC2	Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible	110	.9	7.3	24.5	49.1	18.2	1	8	27	54	20	3.76	.867	
AC3	Use central atriums, courtyards and lobbies (elevators, and stairs can be locate in central areas) for optimum ventilation	110	1.8	.9	13.6	48.2	35.5	2	1	15	53	39	4.15	.822	
AC4	Provide vertical air shafts/stacks, and central exhaust paths to promote interior airflow	110	1.8	2.7	15.5	48.2	31.8	2	3	17	53	35	4.05	.866	
AC5	Use open plan interior to promote interior airflow	110	1.8	7.3	31.8	41.8	17.3	2	8	35	46	19	3.65	.913	

Table D3: Histogram and Frequency of Passive Design Functionality

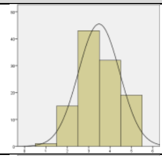
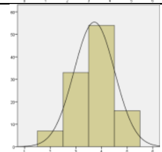
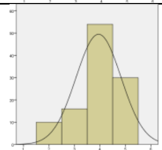
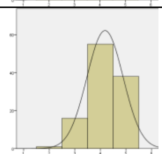
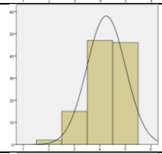
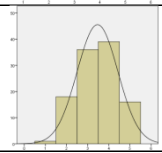
Code	End User factors of Passive Design Functionality	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
AC6	The proportion of the plan is long and narrow (use linear plan form, or a similar strategy) to optimise day lighting	110	9	13.6	39.1	29.1	17.3	1	15	43	32	19	3.48	.965	
AC7	Organise rooms, corridors, stair-wells in a way that uploads a low resistance airflow path through the building	110	0	6.4	30.0	49.1	14.5	0	7	33	54	16	3.72	.791	
AC8	Consider interior surface colours and finishes for optimum day light-ing	110	0	9.1	14.5	49.1	27.3	0	10	16	54	30	3.95	.887	
AC9	Design plan to create buffer zones from the summer radiation	110	0	.9	14.5	50.0	34.5	0	1	16	55	38	4.18	.706	
AC10	Plan specific spaces or functions to coincide with solar orientation	110	0	1.8	13.6	42.7	41.8	0	2	15	47	46	4.25	.756	
AC11	Narrow floor width to optimise natural ventilation	110	.9	16.4	32.7	35.5	14.5	1	18	36	39	16	3.46	.964	

Table D4: Histogram and Frequency of Passive Design Functionality

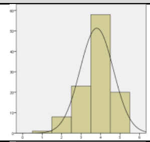
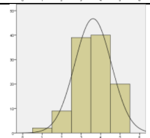
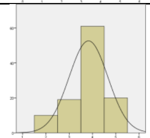
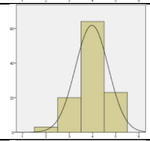
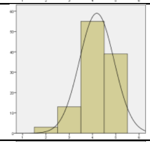
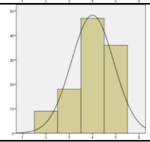
Code	End User factors of Passive Design Functionality	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
AC12	Provide solar-oriented interior zone to store and maximise solar heat gain	110	.9	7.3	20.9	52.7	18.2	1	8	23	58	20	3.80	.855	
AC13	Attenuate plan to promote ventilation	110	1.8	8.2	35.5	36.4	18.2	2	9	39	40	20	3.61	.939	
AC14	Link the exterior and interior airflows by single-sided, cross or stack ventilation	110	0	9.1	17.3	55.5	18.2	0	10	19	61	20	3.83	.833	
AD1	Use roof elements for stack effect ventilation	110	0	2.7	18.2	58.2	20.9	0	3	20	64	23	3.97	.710	
AD2	Use skylight, light tube and clerestory for natural illumination	110	0	2.7	11.8	50.0	35.5	0	3	13	55	39	4.18	.744	
AD3	Use solar roof collectors on the south-oriented surfaces	110	0	8.2	16.4	42.7	32.7	0	9	18	47	36	4.00	.909	

Table D5: Histogram and Frequency of Passive Design Functionality

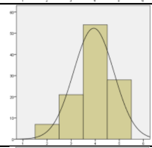
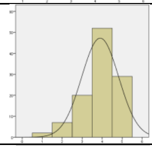
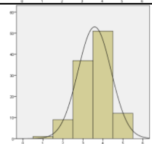
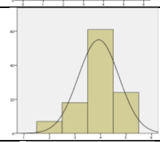
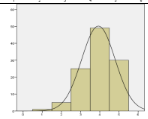
Code	End User factors of Passive Design Functionality	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
AD4	Use double roof and wall construction for ventilation within envelope	110	0	8.2	32.7	38.2	20.9	0	9	36	42	23	3.72	.890	
AD5	Use ventilated roof to lower summer gains through roof	110	0	6.4	19.1	49.1	25.5	0	7	21	54	28	3.94	.838	
AD6	Use of an appropriate shape and angle of the roof for optimum ventilation and thermal comfort	110	1.8	6.4	18.2	47.3	26.4	2	7	20	52	29	3.90	.928	
AE1	Minimise the ratio of exterior surfaces to interior floor areas	110	.9	8.2	33.6	46.4	10.9	1	9	37	51	12	3.58	.828	
AE2	Use high-capacitance materials to store solar heat gain and control heat flow through envelope	110	0	6.4	16.4	55.5	21.8	0	7	18	61	24	3.93	.798	
AE3	Optimise south-facing glazing	110	.9	4.5	22.7	44.5	27.3	1	5	25	49	30	3.93	.875	

Table D6: Histogram and Frequency of Passive Design Functionality

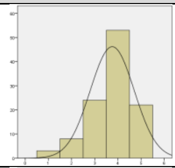
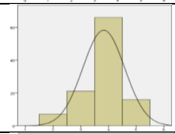
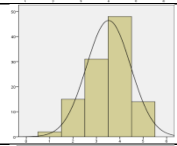
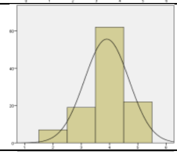
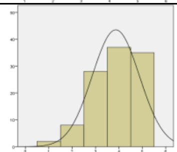
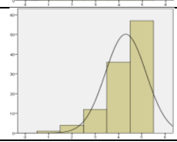
Code	End User factors of Passive Design Functionality	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
AE4	Use Trombe wall or double façade to collect solar gain	110	2.7	7.3	21.8	48.2	20.0	3	8	24	53	22	3.75	.950	
AE5	Locate thermal mass inside the envelope to store heating	110	0	6.4	19.1	60.0	14.5	0	7	21	66	16	3.83	.752	
AE6	Minimise openings in envelope to reduce thermal gain	110	1.8	13.6	28.2	43.6	12.7	2	15	31	48	14	3.52	.946	
AE7	Use solar wall on south-oriented surfaces	110	0	6.4	17.3	56.4	20.0	0	7	19	62	22	3.90	.789	
AE8	Develop details to minimise air infiltration and ex-filtration	110	1.8	7.3	25.5	33.6	31.8	2	8	28	37	35	3.86	1.009	
AE9	Provide shading strategies for wall exposed to summer sun to mitigate unwanted solar gain for optimum ventilation and thermal comfort	110	.9	3.6	10.9	32.7	51.8	1	4	12	36	57	4.31	.875	

Table D7: Histogram and Frequency of Passive Design Functionality

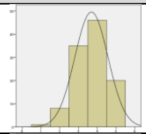
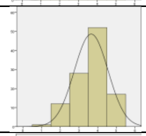
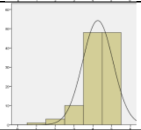
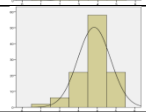
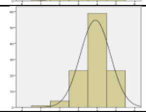
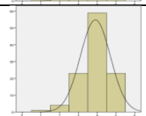
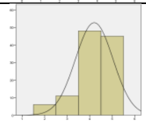
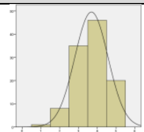
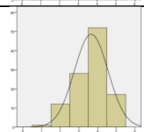
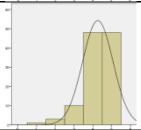
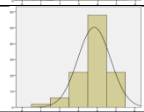
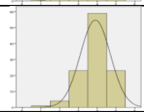
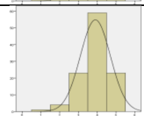
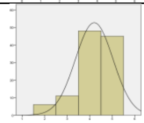
Code	End User factors of Passive Design Functionality	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
AE10	Use louvred wall for maximum ventilation control	110	.9	7.3	31.8	41.8	18.2	1	8	35	46	20	3.69	.886	
AE11	Use exterior elements to direct summer wind flow into the interior	110	.9	10.9	25.5	47.3	15.5	1	12	28	52	17	3.65	.903	
AE12	Orient openings to facilitate natural ventilation	110	.9	2.7	9.1	43.6	43.6	1	3	10	48	48	4.26	.809	
AE13	Details openings to limit undesired air infiltration and ex-filtration as well as to reduce convective gains	110	1.8	5.5	20.0	52.7	20.0	2	6	22	58	22	3.84	.873	
AE14	Provide light shelves to allow daylight to penetrate deep into a building	110	.9	3.6	20.9	53.6	20.9	1	4	23	59	23	3.90	.801	
AE15	Use higher window to wall area ratios to maximise solar access and ventilation	110	.9	10.0	26.4	50.0	12.7	1	11	29	55	14	3.64	.864	
AE16	Provide high levels of insulation in the facade and building envelope to reduce summer conductive gain and to preserve internal heat	110	0	5.5	10.0	43.6	40.9	0	6	11	48	45	4.20	.833	

Table D7: Histogram and Frequency of Passive Design Functionality

Code	End User factors of Passive Design Functionality	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
AE10	Use louvred wall for maximum ventilation control	110	.9	7.3	31.8	41.8	18.2	1	8	35	46	20	3.69	.886	
AE11	Use exterior elements to direct summer wind flow into the interior	110	.9	10.9	25.5	47.3	15.5	1	12	28	52	17	3.65	.903	
AE12	Orient openings to facilitate natural ventilation	110	.9	2.7	9.1	43.6	43.6	1	3	10	48	48	4.26	.809	
AE13	Details openings to limit undesired air infiltration and ex-filtration as well as to reduce convective gains	110	1.8	5.5	20.0	52.7	20.0	2	6	22	58	22	3.84	.873	
AE14	Provide light shelves to allow daylight to penetrate deep into a building	110	.9	3.6	20.9	53.6	20.9	1	4	23	59	23	3.90	.801	
AE15	Use higher window to wall area ratios to maximise solar access and ventilation	110	.9	10.0	26.4	50.0	12.7	1	11	29	55	14	3.64	.864	
AE16	Provide high levels of insulation in the facade and building envelope to reduce summer conductive gain and to preserve internal heat	110	0	5.5	10.0	43.6	40.9	0	6	11	48	45	4.20	.833	

Appendix E – Passive Design Performance Histogram and Frequency Table

Table E1: Histogram and Frequency of Passive Design Performance

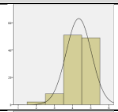
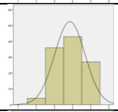
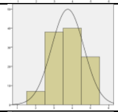
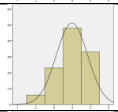
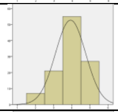
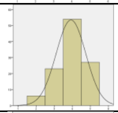
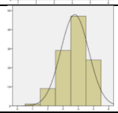
Code	End User factors of Passive Design Performance	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
BA1	Utilising views and orientation	110	0	1.8	7.3	46.4	44.5	0	2	8	51	49	4.34	.694	
BA2	Affect site on visual focus	110	0	3.6	32.7	39.1	24.5	0	4	36	43	27	3.85	.837	
BA3	Enhancement of site to consider identity	110	0	6.4	34.5	36.4	22.7	0	7	38	40	25	3.75	.880	
BB1	Durable, high quality finishes	110	0	5.5	20.9	43.6	30.0	0	6	23	48	33	3.98	.857	
BB2	Select good colour to use	110	0	6.4	19.1	50.0	24.5	0	7	21	55	27	3.93	.832	
BB3	Passive spaces layout allow social interaction	110	0	5.5	20.9	49.1	24.5	0	6	23	54	27	3.93	.821	
BB4	Provide a special character for the space based on building type	110	.9	8.2	26.4	42.7	21.8	1	9	29	47	24	3.76	.918	

Table E2: Histogram and Frequency of Passive Design Performance

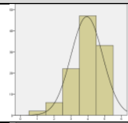
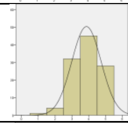
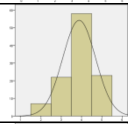
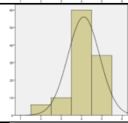
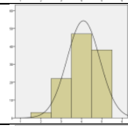
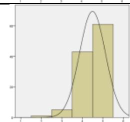
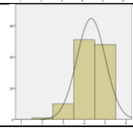
Code	End User factors of Passive Design Performance	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
BB5	Space layout allows for security, way finding, and flexibility of use	110	1.8	5.5	20.0	42.7	30.0	2	6	22	47	33	3.94	.941	
BB6	Space layout enhances or interferes with wellbeing of occupants	110	.9	3.6	29.1	40.9	25.5	1	4	32	45	28	3.86	.872	
BB7	The adequacy of passive design space available for function/activities	110	0	6.4	20.0	52.7	20.9	0	7	22	58	23	3.88	.810	
BC1	The temperature controls provide for the needs of different occupants	110	0	5.5	9.1	54.5	30.9	0	6	10	60	34	4.11	.782	
BC2	Thermal comfort in spaces enhances or interferes with wellbeing of occupants	110	0	2.7	20.0	42.7	34.5	0	3	22	47	38	4.09	.808	
BD1	A comfortable internal air temperature	110	0	.9	4.5	39.1	55.5	0	1	5	43	61	4.49	.632	
BD2	The air quality in space enhances or interferes with wellbeing of occupants	110	0	.9	9.1	46.4	43.6	0	1	10	51	48	4.33	.679	

Table E3: Histogram and Frequency of Passive Design Performance

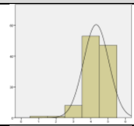
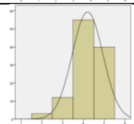
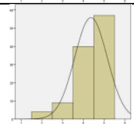
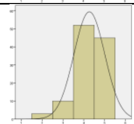
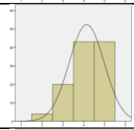
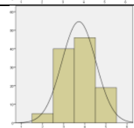
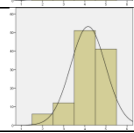
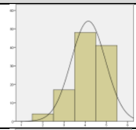
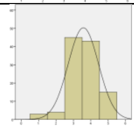
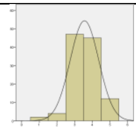
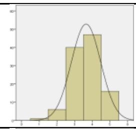
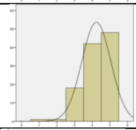
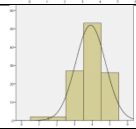
Code	End User factors of Passive Design Performance	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
BD3	The air quality in spaces (i.e. stuffy/stale air, cleanliness and odours)	110	9	.9	7.3	48.2	42.7	1	1	8	53	47	4.31	.726	
BE1	The adequacy of light sufficiency in spaces	110	0	2.7	10.9	50.0	36.4	0	3	12	55	40	4 .20	.739	
BE2	The adequacy of natural light in spaces	110	0	3.6	8.2	36.4	51.8	0	4	9	40	57	4 .36	.787	
BE3	The visual comfort of the lighting (e.g., glare, reflections, contrast)	110	0	2.7	9.1	47.3	40.9	0	3	10	52	45	4.26	.738	
BE4	The lighting quality enhances or interferes with wellbeing of occupants	110	0	3.6	18.2	39.1	39.1	0	4	20	43	43	4.14	.840	
BE5	Atrium or rotunda control devices for optimum space comfort	110	0	4.5	36.4	41.8	17.3	0	5	40	46	19	3.72	.803	
BF1	Select insulation against noises from corridors to give space privacy	110	0	5.5	10.9	46.4	37.3	0	6	12	51	41	4.15	.826	

Table E4: Histogram and Frequency of Passive Design Performance

Code	End User factors of Passive Design Performance	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
BF2	Utilise good acoustic conditions	110	0	3.6	15.5	43.6	37.3	0	4	17	48	41	4.15	.811	
BG1	The horizontal utility systems of passive building logically configured to serve multi-user needs	110	2.7	3.6	40.9	39.1	13.6	3	4	45	43	15	3.57	.872	
BG2	Utility passive design cores uniformly designed and vertically stacked	110	1.8	3.6	42.7	40.9	10.9	2	4	47	45	12	3.55	.808	
BG3	Make the atrium or rotunda adequate for cleaning, maintenance etc	110	.9	5.5	36.4	42.7	14.5	1	6	40	47	16	3.65	.830	
BG4	Reduce consumption of water, energy and electricity	110	.9	.9	16.4	38.2	43.6	1	1	18	42	48	4.23	.820	
BG5	Response time to urgent repair issues	110	1.8	1.8	24.5	48.2	23.6	2	2	27	53	26	3.90	.845	

Appendix F – Passive Design Usability Histogram and Frequency Table

Table F1: Histogram and Frequency of Passive Design Usability

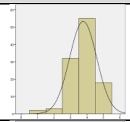
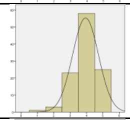
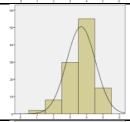
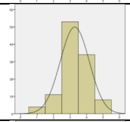
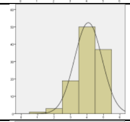
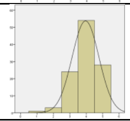
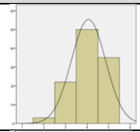
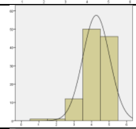
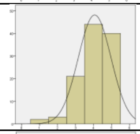
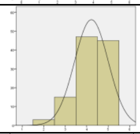
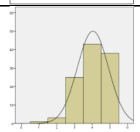
Code	End User factors of Passive Design Usability	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
CA1	Optimum position of service and passive element or equipment for operability	110	1.8	2.7	29.1	50.0	16.4	2	3	32	55	18	3.76	.823	
CA2	Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)	110	.9	2.7	20.9	52.7	22.7	1	3	23	58	25	3.94	.793	
CA3	Group homogeneous passive functions together for efficient operability	110	1.8	7.3	27.3	50.0	13.6	2	8	30	55	15	3.66	.870	
CA4	Avoid slopes and steps of passive space floors	110	3.6	10.0	48.2	30.9	7.3	4	11	53	34	8	3.28	.879	
CA5	Incorporate passive design technologies which are easy to operate by multiple users	110	.9	2.7	17.3	45.5	33.6	1	3	19	50	37	4.08	.836	
CA6	Accessible passive design controls for multiple users	110	.9	2.7	21.8	49.1	25.5	1	3	24	54	28	3.95	.817	

Table F2: Histogram and Frequency of Passive Design Usability

Code	End User factors of Passive Design Usability	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
CA7	Design passive space that is well-suited for multi-user activities and capabilities	110	0	2.7	20.0	45.5	31.8	0	3	22	50	35	4.06	.793	
CA8	Space to provide multi-user comfort (light, fresh air, optimal temperature)	110	.9	.9	10.9	45.5	41.8	1	1	12	50	46	4.26	.762	
CB1	Reduce user stress and feelings of frustration due to lack of space	110	1.8	2.7	19.1	40.0	36.4	2	3	21	44	40	4.06	.911	
CB2	Consider safety, health and physical wellbeing needs for multiple users of passive buildings	110	0	2.7	13.6	42.7	40.9	0	3	15	47	45	4.22	.783	
CB3	Consider different sensing, smelling, hearing, feeling and seeing of users in passive space design	110	0	9.1	20.0	45.5	25.5	0	10	22	50	28	3.87	.900	
CB4	Consider users' cultural image, identity, lifestyle, psychological needs and perceptions in line with passive lighting, ventilation and thermal comfort strategies	110	.9	2.7	22.7	39.1	34.5	1	3	25	43	38	4.04	.877	

Appendix G – Passive Design Flexibility Histogram and Frequency Table

Table G1: Histogram and Frequency of Passive Design Flexibility

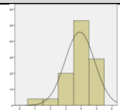
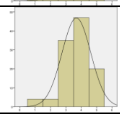
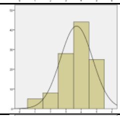
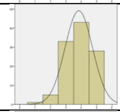
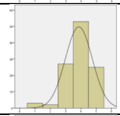
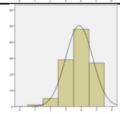
Code	End User factors of Passive Design Flexibility	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
DA1	Passive building structure should be upgradable for future regulations and safety procedures	110	3.6	3.6	18.2	48.2	26.4	4	4	20	53	29	3.90	.957	
DA2	Design passive building to adapt for dysfunctional future utilisation	110	3.6	3.6	31.8	42.7	18.2	4	4	35	47	20	3.68	.938	
DA3	Allow ample floor-to-floor height for future modification	110	4.5	7.3	25.5	40.0	22.7	5	8	28	44	25	3.69	1.047	
DA4	Consider the passive design that accommodates fundamental changes in user preferences	110	.9	4.5	30.0	39.1	25.5	1	5	33	43	28	3.84	.894	
DA5	Design the passive space to cope with changes in flow of users	110	2.7	1.8	24.5	48.2	22.7	3	2	27	53	25	3.86	.883	
DA6	Provide horizontal and vertical circulation and spaces of passive design that encompass future expansion options	110	.9	4.5	26.4	43.6	24.5	1	5	29	48	27	3.86	.872	

Table G2: Histogram and Frequency of Passive Design Flexibility

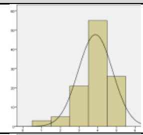
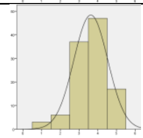
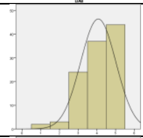
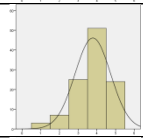
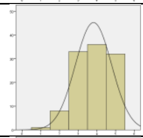
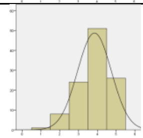
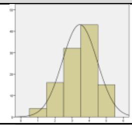
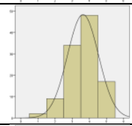
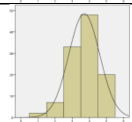
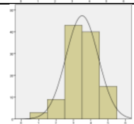
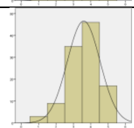
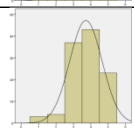
Code	End User factors of Passive Design Flexibility	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
DA7	Design a passive building that responds to the increasing pressures of rapid changes in technology shifts	110	2.7	4.5	19.1	50.0	23.6	3	5	21	55	26	3.87	.920	
DA8	Design passive space that responds to changes in spatial dimensions (volume)	110	2.7	5.5	33.6	42.7	15.5	3	6	37	47	17	3.63	.907	
DA9	Design passive space to respond to changes in climate conditions	110	1.8	2.7	21.8	33.6	40.0	2	3	24	37	44	4.07	.945	
DA10	Design passive layout based on future use scenarios	110	2.7	6.4	22.7	46.4	21.8	3	7	25	51	24	3.78	.952	
DA11	Select the passive building form for change without changing the skeleton	110	.9	7.3	30.0	32.7	29.1	1	8	33	36	32	3.82	.969	
DB1	Specify spaces for multiple use	110	.9	7.3	21.8	46.4	23.6	1	8	24	51	26	3.85	.900	

Table G3: Histogram and Frequency of Passive Design Flexibility

Code	End User factors of Passive Design Flexibility	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
DB2	Use movable walls	110	3.6	14.5	29.1	39.1	13.6	4	16	32	43	15	3.45	1.019	
DB3	Flexible access within and between passive spaces	110	1.8	8.2	30.9	43.6	15.5	2	9	34	48	17	3.63	.907	
DB4	The ability to subdivide large passive design spaces	110	1.8	6.4	30.0	43.6	18.2	2	7	33	48	20	3.70	.904	
DB5	Use modular passive space planning strategies	110	2.7	8.2	39.1	36.4	13.6	3	9	43	40	15	3.50	.926	
DB6	Minimise partitions between passive spaces to control lighting, ventilation and thermal comfort	110	2.7	8.2	31.8	41.8	15.5	3	9	35	46	17	3.59	.941	
DB7	Design passive space to incorporate completely new functions	110	2.7	3.6	33.6	39.1	20.9	3	4	37	43	23	3.72	.930	

Appendix H – Passive Design Reliability Histogram and Frequency Table

Table H1: Histogram and Frequency of Passive Design Reliability

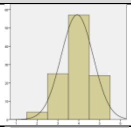
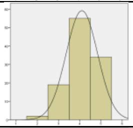
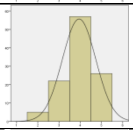
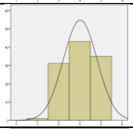
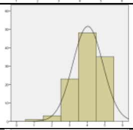
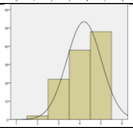
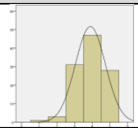
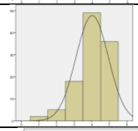
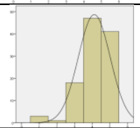
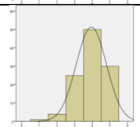
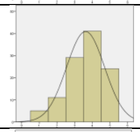
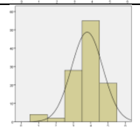
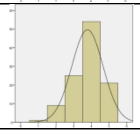
Code	End User factors of Passive Design Reliability	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
EA1	Ensure the passive performance of space or element remains serviceable	110	0	3.6	22.7	51.8	21.8	0	4	25	57	24	3.92	.768	
EA2	Provide optimum drainage and venting to minimise accumulation of moisture	110	0	1.8	17.3	50.0	30.9	0	2	19	55	34	4.10	.741	
EA3	Design passive service life to match user needs	110	0	4.5	20.0	51.8	23.6	0	5	22	57	26	3.95	.788	
EA4	Select components that are resistant to environmental agents	110	0	.9	28.2	39.1	31.8	0	1	31	43	35	4.02	.801	
EA5	Compatibility in joining lighting, ventilation and thermal comfort elements together	110	.9	2.7	20.9	43.6	31.8	1	3	23	48	35	4.03	.851	
EA6	Consider passive design details that are reliable for rainfall, humidity, heavy snowfall, flooding and intense sun degradation	110	0	1.8	20.0	34.5	43.6	0	2	22	38	48	4.20	.822	

Table H2: Histogram and Frequency of Passive Design Reliability

Code	End User factors of Passive Design Reliability	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
EA7	Protect sensitive passive elements from accidental change	110	.9	2.7	28.2	42.7	25.5	1	3	31	47	28	3.89	.850	
EB1	Consider passive building joint seals to resist infiltration of moisture or deleterious materials	110	1.8	4.5	16.4	44.5	32.7	2	5	18	49	36	4.02	.919	
EB2	Use high quality material with long service life to handle passive functions	110	2.7	.9	16.4	42.7	37.3	3	1	18	47	41	4.11	.902	
EB3	Consider the rate of expansion / contraction of material of passive design strategies	110	.9	3.6	22.7	45.5	27.3	1	4	25	50	30	3.95	.855	
EB4	Use standardisation of passive design elements and materials	110	4.5	10.0	26.4	37.3	21.8	5	11	29	41	24	3.62	1.075	
EC1	Specify passive space strategies for user behaviour usage (such as heavy use, accidental impact and interior humidity)	110	3.6	1.8	25.5	50.0	19.1	4	2	28	55	21	3.79	.899	
EC2	Passive building fabric should be adaptable to cyclic change	110	.9	8.2	22.7	49.1	19.1	1	9	25	54	21	3.77	.885	

Appendix I – Passive Design Maintainability Histogram and Frequency Table

Table I1: Histogram and Frequency of Passive Design Maintainability

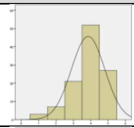
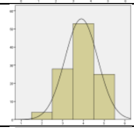
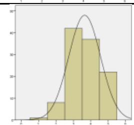
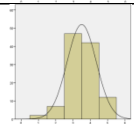
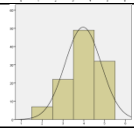
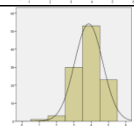
Code	End User factors of Passive Design Maintainability	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
FA1	Provide lighting and ventilation in expected maintenance areas	110	2.7	6.4	19.1	47.3	24.5	3	7	21	52	27	3.85	.960	
FA2	Simplify interface of passive design elements and building facade	110	0	3.6	25.5	48.2	22.7	0	4	28	53	25	3.90	.789	
FA3	Specify simple shape of both building form and space of passive design	110	.9	7.3	38.2	33.6	20.0	1	8	42	37	22	3.65	.915	
FA4	Utilise non-destructive disassembly passive design strategies	110	1.8	6.4	42.7	38.2	10.9	2	7	47	42	12	3.50	.843	
FA5	Eliminate poor detailing of passive design space or element	110	0	6.4	20.0	44.5	29.1	0	7	22	49	32	3.96	.867	
FA6	Design for ease to remove or replace lighting, ventilation and thermal comfort elements	110	.9	2.7	27.3	48.2	20.9	1	3	30	53	23	3.85	.811	

Table I2: Histogram and Frequency of Passive Design Maintainability

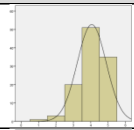
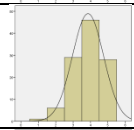
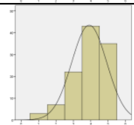
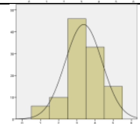
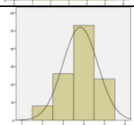
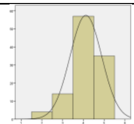
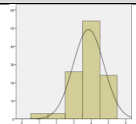
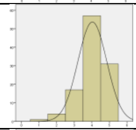
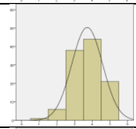
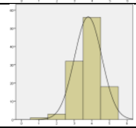
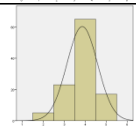
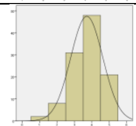
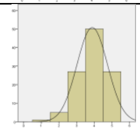
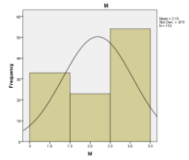
Code	End User factors of Passive Design Maintainability	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
FA7	Design for ease to adjust lighting, ventilation and thermal comfort physical element features	110	.9	2.7	18.2	46.4	31.8	1	3	20	51	35	4.05	.833	
FA8	Design for ease of installing lighting, ventilation and thermal comfort element or material	110	.9	5.5	26.4	41.8	25.5	1	6	29	46	28	3.85	.897	
FA9	Provide passive design strategies that minimise the time for maintenance	110	2.7	6.4	20.0	39.1	31.8	3	7	22	43	35	3.91	1.010	
FB1	Minimise use of unique materials of passive design strategies	110	5.5	9.1	41.8	30.0	13.6	6	10	46	33	15	3.37	1.012	
FB2	Locate lighting, ventilation and thermal comfort materials for operability to minimise degradation	110	0	7.3	23.6	48.2	20.9	0	8	26	53	23	3.83	.844	
FB3	Select materials for lighting, ventilation and thermal comfort strategies for durability and longevity	110	0	3.6	12.7	51.8	31.8	0	4	14	57	35	4.12	.763	

Table I3: Histogram and Frequency of Passive Design Maintainability

Code	End User factors of Passive Design Maintainability	Total Number	Percentage					Frequency of scores (Very Ineffective → Very Effective)					Mean	Std. Deviation	Histogram
			1	2	3	4	5	1	2	3	4	5			
FC1	The cleanliness and maintenance of passive spaces enhances or interferes with wellbeing of occupants	110	2.7	2.7	23.6	49.1	21.8	3	3	26	54	24	3.85	.890	
FC2	The interior of the passive building is designed to be easy to clean and maintain	110	.9	3.6	15.5	51.8	28.2	1	4	17	57	31	4.03	.818	
FC3	Access routes of passive space for transport of maintenance materials	110	.9	5.5	34.5	40.0	19.1	1	6	38	44	21	3.71	.871	
FC4	Critical lighting, ventilation and thermal comfort element should be visible for inspection	110	.9	2.7	29.1	50.9	16.4	1	3	32	56	18	3.79	.779	
FC5	All elements of the external passive building shell should be easy to access for maintenance and cleaning	110	0	4.5	20.9	59.1	15.5	0	5	23	65	17	3.85	.727	
FC6	Optimise sizes for passive design openings for workmanship access	110	1.8	7.3	28.2	43.6	19.1	2	8	31	48	21	3.71	.922	
FC7	Locate passive design elements where they are accessible for maintenance and repair	110	.9	4.5	24.5	45.5	24.5	1	5	27	50	27	3.88	.865	

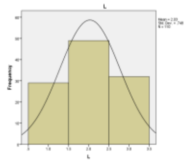
M

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5 Years	33	30.0	30.0	30.0
	5-10 Years	23	20.9	20.9	50.9
	More than 10 years	54	49.1	49.1	100.0
	Total	110	100.0	100.0	



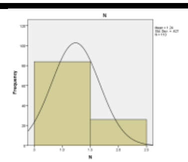
L

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Practicing Architect	29	26.4	26.4	26.4
	Academic and Practicing Architect	49	44.5	44.5	70.9
	Academic Architect	32	29.1	29.1	100.0
	Total	110	100.0	100.0	



N

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes [Contact details]	84	76.4	76.4	76.4
	No	26	23.6	23.6	100.0
	Total	110	100.0	100.0	



Appendix J – Comparative Ranking

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	L1 T.R:29			L2 T.R:49			L3 T.R:32			M1 T.R:33			M2 T.R:23			M3 T.R:54			Overall Ranking		
						S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O
AA1	110	3.82	.950	24.8691	76.36364	3	28	103	3	26	77	3	21	67	2	18	69	3	14	36	3	30	97	3	25	86
AA2	110	4.51	.896	19.867	90.18182	1	2	9	1	1	1	1	1	2	1	3	10	1	1	1	1	1	1	1	1	1
AA3	110	3.95	.956	24.2025	78.90909	2	23	90	2	13	34	2	16	49	3	23	80	2	10	30	2	15	50	2	14	46
AB1	110	3.77	.974	25.8355	75.45455	3	31	108	2	20	58	2	29	102	3	37	120	2	19	49	2	25	88	2	27	91
AB2	110	3.03	1.079	35.6106	60.54545	4	43	132	4	43	131	4	43	132	4	43	132	4	43	132	4	43	132	4	43	132
AB3	110	4.06	.921	22.6847	81.27273	1	13	64	1	5	12	1	12	33	1	14	50	1	9	28	1	9	25	1	9	32
AB4	110	3.75	.933	24.88	74.90909	2	26	98	3	24	70	3	36	117	2	27	94	3	37	111	3	29	95	3	30	98
AC1	110	3.64	.993	27.2802	72.72727	9	29	106	13	39	119	9	31	104	12	39	126	13	39	124	9	28	93	11	36	114
AC2	110	3.76	.867	23.0585	75.27273	5	16	71	7	28	84	11	35	116	8	32	106	8	31	91	7	23	83	8	28	94
AC3	110	4.15	.822	19.8072	82.90909	3	9	42	3	7	16	3	7	14	3	9	29	3	6	20	2	8	23	3	8	20
AC4	110	4.05	.866	21.3827	81.09091	6	18	78	2	6	14	5	10	27	6	17	65	4	7	23	4	10	27	4	10	33
AC5	110	3.65	.913	25.0137	73.09091	10	37	120	8	29	90	13	38	119	9	33	107	7	30	90	11	36	112	10	34	110
AC6	110	3.48	.965	27.7299	69.63636	14	42	131	12	38	118	12	37	118	13	41	130	14	40	126	12	39	116	13	41	127
AC7	110	3.72	.791	21.2634	74.36364	7	20	86	10	36	105	8	30	103	7	29	100	11	35	104	10	31	101	9	32	101
AC8	110	3.95	.887	22.4557	78.90909	4	12	51	9	32	97	4	9	22	4	15	54	6	28	85	5	12	44	5	13	45
AC9	110	4.18	.706	16.89	83.63636	2	7	31	4	8	19	1	2	7	1	6	21	1	2	6	3	7	22	2	6	17
AC10	110	4.25	.756	17.7882	84.90909	1	6	27	1	4	10	2	4	10	2	8	28	2	3	7	1	4	11	1	4	11
AC11	110	3.46	.964	27.8613	69.27273	11	38	122	14	42	124	14	42	128	14	42	131	12	36	109	14	41	119	14	42	128
AC12	110	3.80	.855	22.5	76	13	40	125	5	22	61	6	17	52	11	35	115	10	34	103	6	19	57	7	26	87
AC13	110	3.61	.939	26.0111	72.18182	12	39	124	11	37	114	10	33	108	10	34	114	9	32	96	13	40	118	12	38	119
AC14	110	3.83	.833	21.7493	76.54545	8	22	89	6	25	74	7	24	74	5	16	64	5	26	78	8	26	91	6	24	84
AD1	110	3.97	.710	17.8841	79.45455	2	8	38	4	16	45	5	20	66	5	13	49	5	22	59	3	14	46	3	12	42
AD2	110	4.18	.744	17.799	83.63636	1	4	18	3	12	33	1	3	9	1	2	9	3	18	48	1	6	18	1	7	18
AD3	110	4.00	.909	22.725	80	3	11	50	1	9	28	4	19	65	3	10	34	6	27	82	2	11	43	2	11	40
AD4	110	3.72	.890	23.9247	74.36364	6	35	118	6	31	96	6	26	82	6	26	93	4	21	58	6	33	109	6	31	99
AD5	110	3.94	.838	21.269	78.72727	5	30	107	2	11	32	3	13	35	2	5	20	2	17	47	5	27	92	4	15	51
AD6	110	3.90	.928	23.7949	78	4	25	97	5	19	57	2	11	31	4	12	43	1	8	27	4	24	86	5	18	59
AE1	110	3.58	.828	23.1285	71.63636	14	34	116	16	41	123	13	34	115	14	36	119	16	42	129	13	35	111	15	39	121
AE2	110	3.93	.798	20.3053	78.54545	7	17	77	7	18	47	4	14	44	7	21	76	7	16	46	5	16	51	5	17	55
AE3	110	3.93	.875	22.2646	78.54545	6	15	70	5	15	39	7	22	69	4	11	39	13	33	102	6	17	53	4	16	54
AE4	110	3.75	.950	25.3333	75.09091	11	27	100	13	34	100	10	27	88	5	19	71	10	24	70	11	32	108	11	29	96
AE5	110	3.83	.752	19.6345	76.54545	5	14	69	9	23	66	11	28	100	12	30	103	5	13	35	10	22	82	10	23	83
AE6	110	3.52	.946	26.875	70.36364	15	36	119	15	40	121	16	41	126	16	40	127	14	38	119	16	42	120	16	40	124
AE7	110	3.90	.789	20.2308	78	8	19	85	6	17	46	5	15	48	11	28	97	4	12	33	7	18	55	7	20	62
AE8	110	3.86	1.009	26.1399	77.27273	4	10	49	12	33	99	6	18	64	13	31	105	12	29	88	4	13	45	8	21	70
AE9	110	4.31	.875	20.3016	86.18182	3	5	19	1	2	4	1	5	11	1	1	4	6	15	45	1	2	4	1	2	7
AE10	110	3.69	.886	24.0108	73.81818	13	33	115	11	30	95	12	32	106	9	24	87	9	23	64	15	38	115	12	33	110
AE11	110	3.65	.903	24.7397	73.09091	16	41	126	10	27	78	14	39	120	15	38	124	8	20	57	12	34	110	13	35	111
AE12	110	4.26	.809	18.9906	85.27273	2	3	17	2	3	7	3	8	18	2	4	14	2	5	15	2	3	9	2	3	9
AE13	110	3.84	.873	22.7344	76.72727	9	21	88	8	21	60	9	25	81	8	22	79	11	25	77	9	21	76	9	22	81
AE14	110	3.90	.801	20.5385	78	10	24	93	4	14	35	8	23	71	6	20	75	3	11	32	8	20	67	6	19	61
AE15	110	3.64	.864	23.7363	72.72727	12	32	112	14	35	103	15	40	123	10	25	92	15	41	127	14	37	113	14	37	115
AE16	110	4.20	.833	19.8333	84	1	1	7	3	10	30	2	6	13	3	7	25	1	4	14	3	5	15	3	5	15

Table J-A: User Centred Passive Building Design Attributes: Passive Design Functionality.The abbreviation: L1= Architect practising, L2: Academic and Architect practising, L3: Academic Architect, M1:0-5 years experience, M2:5-10 years experience, M3: More than 10 years Experience, S: Ranking based on sub-attribute, A: Ranking based on Attribute, O: Overall ranking and T.R.: Total Responses

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	L1 T.R:29			L2 T.R:49			L3 T.R:32			M1 T.R:33			M2 T.R:23			M3 T.R:54			Overall Ranking		
						S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O
BA1	110	4.34	.694	15.9908	86.72727	1	1	1	1	5	8	1	3	5	1	3	5	1	2	3	1	5	7	1	3	4
BA2	110	3.85	.837	21.7403	76.90909	2	22	76	2	20	91	2	19	57	2	22	91	2	21	76	2	17	61	2	21	79
BA3	110	3.75	.880	23.4667	75.09091	3	25	87	3	23	107	3	21	73	3	24	102	3	25	108	3	22	85	3	23	97
BB1	110	3.98	.857	21.5327	79.63636	1	7	13	7	22	93	2	16	46	2	15	38	2	14	44	1	14	52	1	14	41
BB2	110	3.93	.832	21.1705	78.54545	2	14	34	5	19	89	3	17	54	3	17	42	7	22	83	2	15	54	3	16	52
BB3	110	3.93	.821	20.8906	78.54545	4	17	48	4	18	83	1	14	38	1	14	37	4	17	55	5	20	74	4	17	53
BB4	110	3.76	.918	24.4149	75.27273	7	20	67	6	21	92	7	25	112	7	27	116	5	18	63	6	21	81	7	22	93
BB5	110	3.94	.941	23.8832	78.72727	3	15	35	2	16	73	5	20	72	4	18	48	3	16	54	3	16	58	2	15	50
BB6	110	3.86	.872	22.5907	77.27273	5	18	53	1	15	69	6	23	90	6	20	66	1	13	43	7	23	87	6	20	71
BB7	110	3.88	.810	20.8763	77.63636	6	19	61	3	17	82	4	18	56	5	19	60	6	20	75	4	18	66	5	19	66
BC1	110	4.11	.782	19.0268	82.18182	1	13	29	1	9	20	2	11	30	1	6	13	2	12	42	1	12	34	1	12	25
BC2	110	4.09	.808	19.7555	81.81818	2	16	41	2	12	29	1	7	17	2	13	27	1	11	26	2	13	37	2	13	27
BD1	110	4.49	.632	14.0757	89.81818	1	2	2	1	1	2	1	1	1	1	1	1	1	3	4	1	1	2	1	1	2
BD2	110	4.33	.679	15.6813	86.54545	3	11	22	2	4	6	2	2	4	3	5	7	2	4	11	2	4	6	2	4	5
BD3	110	4.31	.726	16.8445	86.18182	2	5	6	3	6	9	3	5	8	2	2	2	3	8	19	3	6	8	3	5	6
BE1	110	4.20	.739	17.5952	84	1	3	4	3	8	13	4	12	32	2	9	17	2	6	13	3	9	20	3	8	14
BE2	110	4.36	.787	18.0505	87.27273	2	4	5	1	2	3	2	6	12	3	11	19	1	1	2	1	2	3	1	2	3
BE3	110	4.26	.738	17.3239	85.27273	4	12	23	2	7	11	1	4	6	4	12	24	3	7	18	2	3	5	2	6	8
BE4	110	4.14	.840	20.2899	82.72727	3	6	8	4	13	38	3	10	29	1	8	16	4	9	21	4	10	28	4	11	22
BE5	110	3.72	.803	21.586	74.36364	5	27	102	5	24	110	5	22	87	5	23	101	5	23	85	5	24	102	5	24	102
BF1	110	4.15	.826	19.9036	83.09091	1	8	14	2	11	23	1	8	21	1	4	6	1	10	25	2	11	29	1	9	19
BF2	110	4.15	.811	19.5422	82.90909	2	10	21	1	10	22	2	9	23	2	10	18	2	15	50	1	8	19	2	10	21
BG1	110	3.57	.872	24.4258	71.45455	5	26	101	3	25	117	4	26	125	5	26	113	5	27	128	3	25	117	4	26	122
BG2	110	3.55	.808	22.7606	71.09091	3	23	80	4	26	122	5	27	131	4	25	108	4	26	118	5	27	126	5	27	123
BG3	110	3.65	.830	22.7397	72.90909	4	24	84	5	27	125	3	24	107	3	21	84	3	24	100	4	26	121	3	25	113
BG4	110	4.23	.820	19.3853	84.54545	1	9	16	1	3	5	1	13	37	1	7	15	1	5	12	1	7	14	1	7	12
BG5	110	3.90	.845	21.6667	78	2	21	75	2	14	68	2	15	43	2	16	41	2	19	74	2	19	71	2	18	63

Table J-B: User Centred Passive Building Design Attributes: Passive Design Performance.The abbreviation: L1= Architect practising, L2: Academic and Architect practising, L3: Academic Architect, M1:0-5 years experience, M2:5-10 years experience, M3: More than 10 years Experience, S: Ranking based on sub-attribute, A: Ranking based on Attribute, O: Overall ranking and T.R.: Total Responses

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	L1 T.R:29			L2 T.R:49			L3 T.R:32			M1 T.R:33			M2 T.R:23			M3 T.R:54			Overall Ranking		
						S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O
CA1	110	3.76	.823	21.8883	75.27273	5	9	79	7	10	102	6	10	99	7	11	90	5	9	117	6	10	80	6	10	95
CA2	110	3.94	.793	20.1269	78.72727	6	10	82	4	6	37	4	7	55	3	5	45	7	11	125	4	6	36	5	8	49
CA3	110	3.66	.870	23.7705	73.27273	7	11	111	6	9	109	7	11	105	6	10	88	6	10	122	7	11	104	7	11	109
CA4	110	3.28	.879	26.7988	65.63636	8	12	127	8	11	132	8	12	130	8	12	129	8	12	131	8	12	131	8	12	131
CA5	110	4.08	.836	20.4902	81.63636	3	5	28	2	3	27	2	5	39	2	3	23	6	7	81	2	2	24	2	3	28
CA6	110	3.95	.817	20.6835	79.09091	4	6	32	5	8	64	5	8	62	4	6	53	4	8	87	5	7	40	4	7	44
CA7	110	4.06	.793	19.532	81.27273	2	4	26	3	5	36	3	6	40	5	8	63	5	3	10	3	5	32	3	5	31
CA8	110	4.26	.762	17.8873	85.27273	1	3	20	1	1	15	1	1	3	1	2	8	1	2	9	1	1	12	1	1	10
CB1	110	4.06	.911	22.4384	81.27273	2	2	15	3	7	63	3	4	26	2	4	33	2	4	17	3	8	42	2	4	30
CB2	110	4.22	.783	18.5545	84.36364	1	1	10	1	2	18	1	2	15	1	1	3	4	1	8	2	4	30	1	2	13
CB3	110	3.87	.900	23.2558	77.45455	4	8	66	4	12	80	4	9	63	4	9	83	4	6	69	4	9	60	4	9	67
CB4	110	4.04	.877	21.7079	80.72727	3	7	54	2	4	31	2	3	25	3	7	59	3	5	34	1	3	26	3	6	35

Table J-C: User Centred Passive Building Design Attributes: Passive Design Usability. The abbreviation: L1= Architect practising, L2: Academic and Architect practising, L3: Academic Architect, M1:0-5 years experience, M2:5-10 years experience, M3: More than 10 years Experience, S: Ranking based on sub-attribute, A: Ranking based on Attribute, O: Overall ranking and T.R.: Total Responses

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	L1 T.R:29			L2 T.R:49			L3 T.R:32			M1 T.R:33			M2 T.R:23			M3 T.R:54			Overall Ranking		
						S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O
DA1	110	3.90	.957	24.5385	78	3	4	68	4	4	51	3	3	68	2	2	47	7	8	80	3	3	63	2	2	60
DA2	110	3.68	.938	25.4891	73.63636	9	14	113	9	9	76	11	17	122	9	16	118	4	5	53	10	12	106	10	13	108
DA3	110	3.69	1.047	28.374	73.81818	8	11	99	10	10	86	10	16	121	11	18	125	5	6	62	9	9	96	9	12	107
DA4	110	3.84	.894	23.2813	76.72727	7	10	96	3	3	50	5	8	84	5	9	77	10	11	95	2	5	68	6	7	80
DA5	110	3.86	.883	22.8756	77.27273	6	9	95	6	6	55	2	2	59	3	4	58	3	4	41	7	7	84	4	4	69
DA6	110	3.86	.872	22.5907	77.27273	5	7	81	5	5	54	4	5	77	4	6	68	6	7	68	6	6	73	5	5	72
DA7	110	3.87	.920	23.7726	77.45455	2	3	62	7	7	59	6	10	86	6	10	86	1	1	5	8	8	94	3	3	68
DA8	110	3.63	.907	24.9862	72.54545	11	18	130	11	11	88	7	11	92	8	12	96	9	10	94	11	16	125	11	15	117
DA9	110	4.07	.945	23.2187	81.45455	1	1	39	1	1	40	1	1	19	1	1	12	2	3	24	1	1	49	1	1	29
DA10	110	3.78	.952	25.1852	75.63636	10	16	123	2	2	43	8	12	96	10	17	123	11	12	98	2	2	56	8	9	90
DA11	110	3.82	.969	25.3665	76.36364	4	6	74	8	8	67	9	13	98	7	11	89	8	9	89	1	4	65	7	8	85
DB1	110	3.85	.900	23.3766	76.90909	1	2	47	1	12	98	2	6	78	4	8	74	1	2	16	1	10	100	1	6	78
DB2	110	3.45	1.019	29.5362	68.90909	7	17	128	7	18	129	6	15	111	6	14	111	4	15	116	7	18	130	7	18	129
DB3	110	3.63	.907	24.9862	72.54545	5	13	110	5	16	127	4	9	85	3	7	73	6	17	121	5	15	124	4	14	116
DB4	110	3.70	.904	24.4324	74	3	8	92	3	14	120	3	7	83	2	5	62	3	14	110	3	13	114	3	11	105
DB5	110	3.50	.926	26.4571	70	6	15	121	6	17	128	5	14	101	5	13	99	7	18	123	6	17	129	6	17	126
DB6	110	3.59	.941	26.2117	71.81818	2	5	73	4	15	126	7	18	124	7	15	117	2	13	99	4	14	123	5	16	120
DB7	110	3.72	.930	25.00	74.36364	4	12	105	2	13	108	1	4	76	1	3	57	5	16	120	2	11	105	2	10	100

Table J-D: User Centred Passive Building Design Attributes: Passive Design Flexibility.The abbreviation: L1= Architect practising, L2: Academic and Architect practising, L3: Academic Architect, M1:0-5 years experience, M2:5-10 years experience, M3: More than 10 years Experience, S: Ranking based on sub-attribute, A: Ranking based on Attribute, O: Overall ranking and T.R.: Total Responses

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	L1 T.R:29			L2 T.R:49			L3 T.R:32			M1 T.R:33			M2 T.R:23			M3 T.R:54			Overall Ranking		
						S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O
EA1	110	3.92	.768	19.5918	78.36364	7	11	72	6	10	75	3	3	28	5	6	36	7	10	97	5	8	59	6	9	56
EA2	110	4.10	.741	18.0732	82	4	6	33	2	3	25	2	2	24	3	3	26	5	6	67	2	3	21	2	3	26
EA3	110	3.95	.788	19.9494	78.90909	6	10	60	4	5	44	5	6	53	4	5	32	3	3	52	7	11	70	5	7	47
EA4	110	4.02	.801	19.9254	80.36364	3	5	30	3	4	41	6	8	61	1	1	11	6	9	84	4	7	48	4	6	39
EA5	110	4.03	.851	21.1166	80.54545	2	4	25	5	7	49	4	4	45	6	8	44	2	2	40	3	5	33	3	4	36
EA6	110	4.20	.822	19.5714	84	1	2	11	1	1	17	1	1	16	2	2	22	1	1	29	1	1	10	1	1	16
EA7	110	3.89	.850	21.8509	77.81818	5	7	40	7	11	81	7	10	75	7	10	56	4	4	61	6	9	62	7	10	64
EB1	110	4.02	.919	22.8607	80.36364	2	3	24	2	6	48	1	5	47	2	7	40	1	5	66	3	6	35	2	5	38
EB2	110	4.11	.902	21.9465	82.18182	1	1	3	1	2	24	2	9	70	1	4	31	2	7	73	1	2	16	1	2	24
EB3	110	3.95	.855	21.6456	78.90909	3	8	43	3	8	56	3	7	60	3	9	55	4	13	115	2	4	31	3	8	48
EB4	110	3.62	1.075	29.6961	72.36364	4	13	117	4	13	116	4	12	110	4	12	98	3	11	101	4	13	122	4	13	118
EC1	110	3.79	.899	23.7203	75.81818	1	9	59	2	12	85	2	13	113	1	11	85	1	8	79	2	12	90	1	11	89
EC2	110	3.77	.885	23.4748	75.45455	2	12	109	1	9	62	1	11	97	2	13	104	2	12	114	1	10	69	2	12	92

Table J-E: User Centred Passive Building Design Attributes: Passive Design Reliability.The abbreviation: L1= Architect practising, L2: Academic and Architect practising, L3: Academic Architect, M1:0-5 years experience, M2:5-10 years experience, M3: More than 10 years Experience, S: Ranking based on sub-attribute, A: Ranking based on Attribute, O: Overall ranking and T.R.: Total Responses

Q	N	Mean	Std. Deviation	Coefficient of Variation	Severity Index	L1 T.R:29			L2 T.R:49			L3 T.R:32			M1 T.R:33			M2 T.R:23			M3 T.R:54			Overall Ranking		
						S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O	S	A	O
FA1	110	3.85	.960	24.9351	76.90909	3	6	46	6	10	87	6	11	89	4	8	70	1	1	22	7	15	99	7	12	77
FA2	110	3.90	.789	20.2308	78	7	14	83	5	8	72	1	2	34	1	3	46	3	5	39	6	10	77	4	6	58
FA3	110	3.65	.915	25.0685	72.90909	8	17	104	9	16	112	8	17	114	8	16	112	8	16	107	8	17	107	8	17	112
FA4	110	3.50	.843	24.0857	70	9	19	129	8	15	111	9	18	127	9	17	121	9	18	113	9	18	127	9	18	125
FA5	110	3.96	.867	21.8939	79.27273	2	4	44	3	5	53	3	5	42	3	7	67	5	9	65	2	3	38	2	4	43
FA6	110	3.85	.811	21.0649	77.09091	6	12	63	4	7	71	5	10	80	6	13	95	7	15	106	4	6	47	5	8	73
FA7	110	4.05	.833	20.5679	81.09091	1	3	37	1	2	26	2	3	36	2	5	52	6	13	93	1	1	13	1	2	34
FA8	110	3.85	.897	23.2987	77.09091	5	11	58	7	12	101	4	7	51	5	12	82	4	7	56	5	8	72	6	10	75
FA9	110	3.91	1.010	25.8312	78.18182	4	9	56	2	3	42	7	15	95	7	15	110	2	4	38	3	5	41	3	5	57
FB1	110	3.37	1.012	30.0297	67.45455	3	18	114	3	19	130	3	19	129	3	19	128	3	19	130	3	19	128	3	19	130
FB2	110	3.83	.844	22.0366	76.54545	2	5	45	2	11	94	2	14	94	2	14	109	1	2	31	2	9	75	2	13	82
FB3	110	4.12	.763	18.5194	82.36364	1	1	12	1	1	21	1	4	41	1	2	35	2	6	51	1	2	17	1	1	23
FC1	110	3.85	.890	23.1169	76.90909	2	7	52	5	14	106	3	8	58	4	9	72	4	11	72	3	11	78	4	11	76
FC2	110	4.03	.818	20.2978	80.54545	1	2	36	1	4	52	1	1	20	1	1	30	3	10	71	1	4	39	1	3	37
FC3	110	3.71	.871	23.4771	74.18182	6	15	91	6	17	113	6	13	93	5	10	78	7	17	112	7	16	103	6	15	103
FC4	110	3.79	.779	20.5541	75.81818	5	13	65	7	18	115	2	6	50	2	4	51	5	12	92	6	14	98	5	14	88
FC5	110	3.85	.727	18.8831	77.09091	3	8	55	3	9	79	5	12	91	3	6	61	2	8	60	4	12	79	3	9	74
FC6	110	3.71	.922	24.8518	74.18182	7	16	94	4	13	104	7	16	109	7	18	122	6	14	105	5	13	89	7	16	104
FC7	110	3.88	.865	22.2938	77.63636	4	10	57	2	6	65	4	9	79	6	11	81	1	3	37	2	7	64	2	7	65

Table J-F: User Centred Passive Building Design Attributes: Passive Design Maintainability.The abbreviation: L1= Architect practising, L2: Academic and Architect practising, L3: Academic Architect, M1:0-5 years experience, M2:5-10 years experience, M3: More than 10 years Experience, S: Ranking based on sub-attribute, A: Ranking based on Attribute, O: Overall ranking and T.R.: Total Responses

Appendix K – Rotated Component Matrix

Code	Component																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
AA1	.057	.046	-.007	-.022	.020	.023	-.018	-.004	-.020	.046	.006	.015	-.006	.091	-.134	.014	-.021	.019	-.133	.084	.014	.009	-.006	.048	-.139	.130	.029	.031	-.015	.042	.019	.056	-.145
AA2	.015	-.070	-.031	-.004	.057	-.024	-.022	.069	-.007	.004	.081	.095	.036	.160	.040	-.013	-.054	-.030	.017	.079	.027	-.046	-.006	.057	-.024	.080	.075	-.036	.041	.017	-.035	-.056	-.016
AA3	-.014	.072	.082	.021	.003	.050	.050	-.040	.008	.006	.114	.099	-.001	-.069	.083	.059	-.038	.031	.022	.078	-.049	-.022	.076	-.041	.028	.054	-.024	.093	.063	.032	-.133	.017	-.051
AB1	-.027	-.076	-.110	-.050	-.044	-.025	-.021	.090	.001	-.080	.056	.122	.096	.048	-.001	-.026	-.072	-.094	-.040	-.019	.015	-.082	.107	.034	.092	-.028	.078	-.002	-.085	-.013	.017	.062	.036
AB2	-.004	.010	.000	-.057	-.011	.017	-.039	-.023	.011	.008	-.029	-.087	.006	-.005	-.004	-.005	-.037	.032	.019	-.056	-.015	.000	.316	.005	-.008	-.042	-.007	.008	-.013	.035	-.020	.017	-.017
AB3	.025	.030	.008	.010	-.007	.013	.042	-.057	.032	.020	.025	.093	-.120	.055	-.018	-.025	.059	-.023	-.073	.083	.052	.029	.123	.096	-.019	-.025	.122	.045	.047	-.082	.012	-.019	.050
AB4	-.024	-.032	-.002	.010	-.013	.037	-.026	.030	-.003	.015	.014	.336	-.009	-.019	-.013	.006	-.012	.041	-.009	-.014	.008	-.005	-.089	-.015	-.014	-.032	-.012	.000	-.006	.062	-.027	.000	-.063
AC1	.017	.012	.015	.025	-.029	-.001	-.010	-.004	-.056	-.020	-.001	-.023	-.022	.380	-.001	-.022	-.036	.034	-.012	-.016	-.017	.065	-.006	-.038	.000	.011	.028	.000	-.004	-.032	.010	-.013	.022
AC2	-.048	.111	.059	.005	.031	.038	-.044	-.037	-.075	-.031	-.069	.062	-.038	-.091	.008	.225	-.090	.064	.018	-.038	-.023	.010	.073	.047	-.037	-.029	-.019	.018	-.069	-.045	.004	.052	.020
AC3	.018	-.020	.013	.023	.141	-.029	-.038	-.024	.039	.008	-.029	-.032	-.022	.094	.037	.027	.009	-.026	-.038	.027	-.022	-.080	.128	-.011	-.233	.043	-.036	-.008	.059	-.026	.071	-.036	.031
AC4	-.006	.023	.004	.042	-.030	-.047	-.037	.011	.026	.057	-.063	.147	-.030	-.030	-.015	.013	-.057	-.091	-.005	-.031	.041	-.112	.040	-.027	-.053	.089	-.011	-.042	-.048	-.019	.131	-.016	.129
AC5	.025	-.004	-.058	.080	-.038	-.014	.048	-.007	-.159	-.019	-.069	.028	.073	.002	-.028	.055	.127	-.020	-.056	.013	-.001	-.135	.107	.087	-.013	-.002	.039	.073	.078	.021	.052	-.045	.106
AC6	.015	.096	.055	.000	-.011	.222	-.031	-.101	-.005	.017	-.015	.101	-.049	.024	.031	-.018	-.023	.012	.003	-.002	.021	.021	.052	.036	.075	.057	-.041	-.020	.108	-.044	.014	.008	-.008
AC7	.050	.096	-.013	.082	-.086	.002	.043	-.015	.117	-.096	.045	.015	.000	-.028	.018	-.016	.034	-.084	.042	-.029	.084	.100	.146	-.091	-.034	.080	-.041	.087	-.002	-.026	.075	-.024	.049
AC8	-.022	.045	-.034	.035	.106	.141	-.034	.115	.030	-.014	.027	-.123	.103	-.043	.023	.062	.023	.013	.008	.060	.028	-.063	-.002	-.100	-.037	.000	.041	.029	.022	.019	.022	.095	.046
AC9	-.014	.058	.003	.026	.064	.019	-.085	.185	.051	-.050	-.006	-.006	-.039	.070	-.003	.003	-.017	.002	.020	-.026	.033	.082	-.036	-.070	-.061	.135	-.032	.144	.062	.030	.085	-.060	-.035
AC10	-.004	-.047	-.011	.006	.010	.033	.009	.301	.001	.030	.013	.049	-.032	-.012	.031	.006	.005	-.024	-.046	.005	-.022	.018	-.015	.028	.009	-.049	.012	.003	.005	-.016	-.054	.023	.022
AC11	-.043	-.031	-.010	-.006	.002	.303	.000	.043	-.015	.014	-.012	-.004	-.004	-.015	-.007	.010	-.007	.047	.018	.021	.010	.025	-.034	-.017	-.008	-.018	-.028	-.011	-.045	.034	.000	-.074	-.010
AC12	.015	-.043	-.058	.047	-.019	.051	.000	.089	-.032	-.002	-.157	-.026	.072	.016	.084	-.043	-.055	.054	-.060	.009	.047	-.045	.018	-.070	-.001	.054	.090	.064	-.256	-.058	.064	.008	.006
AC13	-.021	-.011	.011	-.047	-.246	.036	.098	.079	-.031	-.037	-.058	.089	.082	.027	-.060	-.051	.069	-.037	-.005	-.018	-.081	-.001	.003	.028	-.010	.027	-.006	-.007	.044	.004	-.005	.055	.034
AC14	.070	.039	.175	-.128	-.011	.063	-.052	.002	-.074	.039	-.028	.021	-.017	-.039	.020	.022	.008	-.083	.028	.021	-.004	-.025	-.036	-.009	-.043	-.146	.012	.065	-.011	-.030	.006	.068	.046
AD1	.005	-.088	.038	.003	.008	.161	-.011	.020	.004	.027	.124	-.022	.025	.075	.052	-.125	.115	.011	-.073	-.149	.085	-.021	.059	-.018	-.005	.000	.011	-.031	-.047	-.019	-.006	.070	.123
AD2	-.008	-.009	.014	.008	-.015	.015	-.026	-.012	.010	-.006	.018	-.074	-.007	.001	.035	.024	-.029	-.016	.016	.006	-.005	.051	-.022	-.001	.006	-.033	-.014	-.006	.017	.068	-.014	-.030	.378
AD3	-.027	-.052	.059	.043	.022	-.067	-.018	.081	.035	-.069	.005	.053	.042	-.013	.002	-.020	.022	.008	-.019	-.075	-.064	-.054	.053	.029	-.017	-.039	.006	.038	-.063	-.028	-.183	.055	-.005
AD4	-.052	.002	.265	.003	.057	.037	.048	.003	-.009	-.014	-.019	.019	.015	.055	.048	-.052	.054	.004	-.007	.016	.008	.031	.019	.022	.035	.007	.045	.032	.090	.001	.025	-.021	-.055
AD5	.061	.044	.093	.054	-.007	-.016	-.033	-.036	.003	-.008	-.109	.005	.010	.010	.110	-.033	.009	.122	-.002	-.004	-.042	-.014	-.007	.056	.008	.069	.012	.047	.039	.122	-.092	-.014	-.100
AD6	.082	.011	-.030	-.061	-.034	.016	.097	.010	-.066	-.179	-.012	-.010	.076	-.001	.104	-.021	.014	-.022	-.018	.101	-.037	.019	-.029	.044	.048	-.010	.024	.051	-.035	.064	-.032	-.058	-.061
AE1	-.032	-.018	-.018	-.017	.004	-.020	-.038	-.025	-.002	-.368	.049	-.025	-.002	.015	.018	.004	.001	-.032	-.013	-.012	-.004	-.004	-.019	-.035	-.030	.008	-.017	-.026	-.006	-.002	-.003	-.004	.017
AE2	-.015	.035	.031	-.041	-.027	.003	-.001	-.056	-.028	-.054	.043	.023	-.086	.055	-.013	-.047	-.013	.014	-.046	-.023	-.022	.001	-.034	.043	-.007	-.023	.020	-.015	-.295	.049	-.053	-.024	-.011
AE3	.100	.000	.017	.007	-.045	.052	-.035	-.041	.025	-.141	.006	.021	-.017	-.026	-.001	.004	.046	.009	-.026	-.026	.054	.014	-.047	.067	.014	.005	.051	-.224	-.083	-.096	-.016	.053	.029
AE4	.031	-.017	.273	.017	-.004	-.019	-.038	-.019	.016	.033	.029	-.026	-.012	-.003	-.048	.056	-.047	-.024	-.027	-.024	-.002	.051	-.036	-.032	-.003	.044	.045	-.049	-.084	.048	-.067	-.041	.090
AE5	.001	.056	.030	.080	-.003	.014	-.014	.040	.004	-.003	-.037	.041	.001	-.015	.073	.060	-.013	-.052	.042	.006	-.006	-.010	-.020	-.034	.050	.020	-.040	-.047	-.031	-.025	-.248	.020	-.001
AE6	-.008	.019	.017	.042	.059	.024	-.046	-.011	.001	-.074	.026	-.002	.056	.026	-.053	-.028	.005	-.012	.018	.305	-.053	.026	-.062	-.062	.030	-.070	.030	.006	.003	.026	-.009	.034	.046
AE7	.069	-.038	.009	.028	.061	.050	-.056	.033	.017	.047	-.035	.035	.036	-.025	-.082	-.012	-.010	-.054	.027	.191	-.029	-.011	-.039	-.011	-.118	.019	-.038	-.183	-.030	-.086	-.033	.047	.055
AE8	-.033	.041	.005	-.030	-.021	.041	-.005	-.019	-.015	-.011	.040	.019	.015	.005	-.001	.012	.016	.012	-.067	-.026	.346	.032	-.019	.008	.023	-.021	.024	-.018	.013	-.007	.029	.000	.021
AE9	-.022	.005	-.012	.046	.067	.051	-.030	-.115	-.001	-.065	-.057	.002	-.013	-.017	.084	-.077	.140	.026	.039	-.009	.120	.001	-.107	.152	-.081	.065	.027	.039	.042	.011	-.085	.023	-.005
AE10	-.038	-.067	-.018	-.013	.014	.003	.003	-.007	-.098	-.011	-.040	.035	-.002	-.038	-.027	-.023	-.022	.024	.006	-.095	.010	.004	-.006	.065	.012	-.107	-.022	.030	.037	.334	.046	-.011	.058
AE11	-.013	.008	-.009	-.034	-.020	.030	.015	-.038	.062	-.025	.016	.015	.088	-.029	.043	-.045	.022	-.086	.083	-.004	-.028	.010	.095	-.035	-.078	-.073	-.068	.037	-.073	.147	-.039	.005	.033
AE12	.067	.076	-.040	-.012	.022	.020	-.014	-.036	-.018	-.049	.027	.020	.022	-.093	-.029	-.043	.035	.034	.147	.066	-.011	-.103	.047	-.001	-.099	-.008	.061	.002	-.032	.097	-.052	-.034	-.052
AE13	.034	.065	-.004	-.019	-.047	-.044	-.033	.014	-.005	.091	-.032	.044	.007	.027	.033	-.075	.026	-.056	.004	-.023	.159	-.049	-.001	-.009	.013	-.038	-.084	.095	-.092	.008	.009	.001	-.071
AE14	-.021	.045	.016	.034	-.024	.008	-.013	.016	.056	.026	.014	.022	-.037	-.004	-.014	.027	.001	-.044	-.029	.036	-.018	.075	-.026	-.098	.021	.041	.048	-.066	-.043	.300	-.046	-.014	.037
AE15	-.045	.029	.020	-.028	.001	-.004	-.013	-.023	-.004	.044	-.344	-.006	.004	-.018	.003	.013	.019	-.034	-.012	-.030	-.024	.025	.012	.010	.034	-.028	-.020	-.007	.000	.030	-.006	-.019	.005
AE16	-.117	.057	-.040	.056	.016	-.078	-.009	-.068	-.082	-.108	-.084	.013	-.003	.009	-.027	-.068	.020	.056	.008	.004	-.004	-.018	-.033	.030	-.026	.056	-.059	.086	-.049	-.025	-.021	.056	.170
BA1	.019	-.034	-.037	-.066	.060	.025	.004	-.050	.026	-.027	-.059	.077	.040	.087	.038	.158	-.049	.010	-.056	.007	-.025	.071	-.085	.057	.000	.017	.006	-.018	.086	-.005	-.033	-.033	.074
BA2	-.007	-.021	-.060	-.232	.004	.056	-.039	.012	.047	-.106	-.002	-.024	-.026	.021	-.071	-.011	-.014	.033	-.007	-.063	-.045	.022	.042	.073	-.090	-.053	-.017	-.066	-.087	-.017	.031	-.036	-.016
BA3	.011	.041	.036	-.336	-.026	-.005	-.032	-.031	-.006	.008	.005	-.019	.011	-.039	.028	-.033	-.009	-.026	.014	-.010	.028	.001	.017	-.023	.020	-.017	.043	.009	.000	-.003	.018	.044	-.030
BB1	.036	-.042	-.057	-.160	.076	-.039	.012	.002	-.039	.002	-.001	.004	.031	-.035	.007	.098	.040	.018	-.005	-.054	.013	.071	.011	-.018	-.033	.002	.009	.034	-.015	.002	-.017	-.047	.043
BB2	-.020	.043	.046	-.042	.322	.006	.033	.055	-.043	-.048	-.029	.017	-.040	-.030	-.040	-.048	.018	-.069	-.013	.028	-.052	.030	-.019	.035	.000	-.052	-.009	.005	.056	-.017	.005	.012	-.021
BB3	.117	-.077	-.027	-.001	.019	-.018	.087	.041	.000	-.006	-.033	.039	.069	-.013	-.017	-.061	.070	.043	-.025	.038	.018	.046	.025	-.077	-.039	.021	-.018	-.026	.030	-.085	-.048	-.082	.039
BB4	-.011	-.013	-.060	-.103	.048	-.005	-.018	.078	-.020	.089	-.082	.040	.052	-.074	-.036	-.003	.022	-.057	.014	.138	.035	.044	.024	-.099	-.008	.060	-.058	.032	.014	-.077	-.092	-.070	.063
BB5	-.048	.054	-.043	-.037	.051	-.072	.022	.034	-.016	-.051	.001	.026	.008	-.024	-.041	-.074	-.092	.080	-.014	.039	.104	-.002	-.045	.047	.040	-.069	-.117	.116	.035	.013	-.106	-.067	.069
BB6	-.010	.058	.049	-.005	-.096	-.060	.044	.095	.120	.009	-.015	-.030	.062	.032	-.077	.046	-.004	.033	-.108	-.027	.069	-.023	.022	.002	-.014	-.004	.008	-.024	.133	-.010	-.132	.079	.002
BB7	.009	-.016	.037	-.028	.015	-.036	.034	.107	-.020	.026	.012	-.061	.062	.087	-.033	-.054	-.011	.146	.016	.023	.052	-.079	-.010	.007	-.042	-.039	.015	.018	.029	-.070	-.087	-.001	-.058
BC1	.004	-.032	-.047	-.022	-.074	.091	-.059	-.042	.025	.074	.040	.051	-.023	-.006	-.043	.004	.039	.286	-.029	-.011	.001	.024	.012	.003	.017	-.086	.019	.003	-.044	.000	-.008	.035	.058
BC2	-.058	.000	-.003	-.020	-.027	-.006	-.024	.004	.300	-.014	-.001	-.018	-.074	-.089	.001	-.011	.049	-.035	-.017	.002	-.001	.074	.053	.011	.043	-.010	.056	.022	.026	-.003	-.032	.001	.058

Table K-A: Rotated Compenent Matrix

Code	Component																																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
BD1	-.003	.001	-.026	-.034	.043	-.050	-.026	-.002	.175	-.013	-.041	.102	-.012	.032	.071	-.033	-.027	.079	.057	-.071	-.043	-.034	-.017	-.024	-.027	.003	.028	.010	.004	-.003	.061	-.019	-.016
BD2	.002	.047	-.020	.013	.028	.032	-.067	.009	.158	-.004	-.078	.029	.049	.060	.011	-.054	.010	.131	.025	.024	-.017	.010	-.046	-.046	-.071	.007	-.014	-.027	.007	.020	-.008	.043	-.032
BD3	-.099	.006	-.056	-.089	-.103	.030	.054	-.102	.043	-.043	.000	-.023	.046	.061	.040	-.008	.097	.106	-.029	.026	-.021	-.153	-.126	-.073	-.064	.021	-.025	.035	-.032	-.029	.015	.002	-.014
BE1	-.028	.014	-.012	-.038	-.012	.030	.050	-.002	.014	-.050	.037	.048	-.019	-.023	.003	.022	.005	.090	.037	-.050	-.003	-.118	.053	-.062	.098	.042	.013	-.139	.109	-.042	.020	-.020	-.039
BE2	-.012	.049	-.034	.020	.024	.011	.110	.082	.057	-.105	.024	-.089	-.017	-.033	-.017	-.021	-.086	.018	.105	.010	-.006	-.044	.045	.066	.048	.095	.091	-.133	.041	.034	-.043	-.084	-.015
BE3	-.092	-.028	.045	-.029	-.087	.028	.013	-.039	-.030	-.010	.008	-.021	.008	.031	-.011	-.010	-.003	-.053	.034	-.026	-.033	-.023	-.104	.013	-.018	.284	-.031	.016	.001	-.039	-.030	.014	.066
BE4	.031	.059	.053	-.053	-.069	-.043	.216	.007	.036	.038	-.075	-.024	-.033	-.002	.006	-.077	-.059	-.042	-.016	-.088	.011	-.007	-.024	.048	.047	.014	.026	-.030	.092	-.024	-.056	.036	.071
BE5	-.009	-.036	.025	.083	-.037	.021	.074	.078	.011	-.011	.041	-.123	-.050	.031	.045	-.064	.025	.063	.004	-.017	-.034	.000	.141	.034	-.062	.035	-.138	-.018	.055	.013	-.033	-.078	.042
BF1	.009	.090	.048	-.004	.041	-.028	.114	.015	-.052	.017	.011	.033	.001	.056	.016	.030	-.088	.212	.004	-.052	.011	.056	.049	.007	.066	-.045	-.040	.004	-.022	-.006	.132	-.007	-.044
BF2	.041	.010	-.019	.027	-.021	-.017	.207	.080	-.068	.024	.012	.016	-.034	.007	-.026	.017	.004	.077	-.007	.000	-.013	.008	-.094	.034	-.044	-.041	-.034	.041	-.002	.034	-.009	-.079	-.017
BG1	-.049	.032	.048	-.021	-.062	-.059	.005	-.112	.074	.001	-.009	-.046	-.033	.065	-.015	.043	.001	.004	.031	.003	.087	-.073	-.015	-.086	-.024	-.132	-.053	.049	-.023	-.047	-.046	-.028	.000
BG2	-.064	.063	.048	-.039	-.006	.012	-.045	-.016	.049	-.001	.019	-.018	-.011	-.026	-.052	-.005	-.029	.024	.035	-.018	.017	-.103	.020	-.151	.169	-.034	-.014	-.044	.025	.108	.015	.021	-.043
BG3	-.014	.041	-.048	.031	.012	.042	-.035	-.004	-.068	-.023	-.006	.010	.027	-.038	.027	-.005	-.006	.013	-.004	-.023	-.024	-.006	-.008	.006	-.019	.002	-.388	-.002	.042	-.013	.002	.035	.032
BG4	.030	.013	-.017	.013	.001	-.027	-.026	.019	-.041	-.012	.014	.027	-.025	-.046	-.038	-.036	-.009	-.024	-.017	-.011	-.016	-.308	-.001	-.021	-.010	-.011	-.032	-.008	-.028	-.023	-.027	-.034	-.005
BG5	.034	.042	-.012	-.039	.060	-.104	-.077	.016	.051	-.044	-.015	.050	.059	.049	.035	-.028	.031	-.112	.041	-.023	.045	.038	-.010	-.015	.055	.076	-.136	-.095	-.043	.051	.049	-.074	-.029
CA1	.018	-.028	.053	-.007	-.015	-.061	-.064	.099	.025	.005	-.030	.017	.000	.075	-.053	.239	.023	-.030	.009	-.010	-.001	.083	-.042	-.072	-.028	-.043	.030	-.037	.108	.041	-.009	-.001	-.007
CA2	.056	.087	-.025	.031	.015	-.040	.010	.055	-.034	-.050	-.184	-.049	-.087	.004	.043	.024	-.096	-.040	.066	-.001	-.003	-.078	-.033	.014	-.002	-.131	.032	.044	.046	.026	.142	.070	.011
CA3	.045	.009	.029	.006	-.053	.048	.022	-.064	.059	-.081	-.050	-.017	-.146	-.005	-.031	.028	-.014	-.093	-.070	.023	-.056	-.049	-.126	.082	.101	-.082	.007	.036	.066	-.008	-.039	.010	.011
CA4	-.003	-.025	-.026	.030	-.008	.055	.065	-.031	-.005	-.042	.002	.025	.002	.111	-.024	.032	-.011	.015	-.036	.024	-.057	-.041	-.009	-.333	-.012	.010	.022	.012	.009	.034	-.013	.037	-.036
CA5	-.005	.006	.026	.017	.051	.015	-.007	-.014	.016	.007	.009	.007	-.344	.042	.000	-.035	.026	-.021	-.024	-.057	-.034	.011	-.010	-.010	-.050	-.060	.036	-.015	-.021	.001	.021	.020	.010
CA6	.055	.014	-.104	-.007	-.059	-.007	.004	.069	-.013	.014	.051	.052	-.203	-.032	.011	-.063	-.012	.011	.074	-.038	.000	.035	-.007	-.067	.025	.063	.014	.040	.021	.033	-.038	.026	-.006
CA7	-.017	.001	-.004	.007	-.056	.062	.037	.003	.076	.018	.035	-.036	-.059	-.032	-.082	.053	-.084	-.011	.004	.045	.000	-.086	-.102	.061	-.008	-.026	.009	.169	.003	-.016	-.062	-.034	.021
CA8	.055	-.011	-.002	-.018	-.025	.001	.017	.027	.128	.030	.014	-.029	.058	.079	-.025	.003	-.068	-.020	-.005	-.038	-.031	-.018	-.039	.065	-.016	-.079	-.008	.102	-.079	-.016	.082	-.030	.141
CB1	-.023	-.034	-.053	-.023	.083	.029	.140	-.020	.011	-.014	.006	.013	-.133	-.049	-.059	-.016	-.080	-.044	-.037	-.084	.021	.040	-.043	-.032	-.006	.102	-.054	-.145	-.051	.067	.032	-.047	-.019
CB2	.028	.040	-.013	.027	-.039	-.094	.065	-.001	.107	.034	.014	.003	.020	-.040	.019	.052	.043	.037	.009	.087	.004	-.001	.004	.001	.066	-.025	-.024	-.157	-.059	.000	.043	-.019	-.032
CB3	.014	.077	-.009	-.032	-.062	-.041	-.003	-.011	-.008	.057	-.040	-.103	-.045	-.028	.035	.098	-.013	.047	-.004	.063	-.002	.096	.054	-.016	.016	.085	-.050	-.063	-.126	-.006	-.057	-.009	.023
CB4	-.087	-.016	.044	-.095	-.056	-.026	-.010	-.016	-.021	.058	.058	-.051	-.005	.000	.003	-.020	.023	.093	.021	.204	.067	.021	-.023	.037	-.058	.043	-.004	-.040	.018	.019	.073	.002	-.001
DA1	-.031	-.104	-.001	.061	.018	-.107	.022	-.018	-.026	-.026	-.027	-.031	-.023	-.045	.013	-.013	-.028	.053	.019	.087	.108	.022	.012	.039	-.037	.013	.013	-.037	.000	.037	-.022	-.020	.027
DA2	-.081	-.154	.035	.031	-.018	-.023	.015	-.015	.056	.021	-.039	.071	-.022	-.017	.010	-.033	.013	-.006	.066	-.024	-.073	-.064	.061	-.073	-.057	-.044	-.062	.004	-.057	-.024	-.032	.017	-.065
DA3	-.104	-.148	-.044	-.002	.029	.061	.030	-.073	.033	.033	-.066	.053	-.065	.021	.115	.069	-.016	-.074	-.017	-.026	.061	-.041	-.002	-.097	.081	-.053	-.016	.069	.042	-.010	.051	-.007	-.009
DA4	.062	-.022	-.083	.059	-.070	-.012	-.012	.032	.009	-.011	-.050	-.014	.013	-.041	.103	.154	.070	.022	-.082	.077	.049	-.018	.038	.045	-.021	.008	.028	.097	.059	.025	.100	.020	-.015
DA5	.024	-.007	.109	-.001	-.030	.001	.105	-.029	-.022	.010	-.010	.045	.013	-.056	.005	.041	-.030	.013	-.001	.116	-.007	.008	-.001	-.009	.028	.027	-.020	.027	-.038	-.070	.200	-.073	.011
DA6	-.038	-.124	.080	-.002	-.011	.013	-.007	-.006	-.019	-.050	.002	-.007	-.050	-.073	-.004	.009	-.082	.014	.003	.043	.070	-.011	-.012	.046	.000	.033	.010	.001	-.003	-.012	.095	.015	-.024
DA7	.041	-.045	.008	.004	.023	.015	-.056	.017	-.014	-.031	-.101	.020	-.020	.063	.044	-.052	-.061	.037	-.033	-.017	-.051	.026	-.048	-.003	.208	.118	-.046	.003	.055	.015	-.022	-.036	-.049
DA8	-.037	-.142	.104	.003	-.029	-.012	-.064	.002	-.042	-.066	-.044	.017	-.045	.054	-.009	-.010	.009	.004	.016	-.013	-.056	.013	.063	-.026	.008	.031	-.045	-.064	.059	-.039	.079	.030	-.025
DA9	-.035	.067	.086	-.034	.015	-.077	-.079	-.016	.022	-.031	.003	.040	-.035	-.048	-.110	-.051	.002	.007	-.016	-.011	-.018	.057	.095	-.023	.053	.153	.015	.225	-.069	-.103	.008	.022	-.029
DA10	-.021	-.028	-.029	-.060	-.090	.050	.010	.012	-.028	.013	.010	-.061	-.127	.042	.105	-.001	-.023	-.083	-.076	.161	-.035	-.061	-.028	.131	.058	-.013	-.100	.013	-.024	-.044	.021	-.007	-.065
DA11	-.042	-.004	-.029	.040	-.025	-.017	-.050	.084	.019	-.012	.057	-.056	-.138	-.089	.001	.047	.049	.024	-.048	.070	.025	-.076	.030	.075	.028	.027	-.036	-.052	-.038	.083	.026	-.059	-.074
DB1	.032	-.125	-.033	-.024	.012	-.004	.044	-.023	.018	.058	.066	.041	-.040	-.018	-.006	.050	-.051	-.039	-.044	.023	-.050	-.021	.027	.021	.060	.028	.012	.078	.042	-.003	-.028	-.025	.069
DB2	.230	.017	.048	-.008	-.064	-.027	-.013	-.002	-.064	-.003	.014	.029	-.092	.007	.014	-.005	-.012	.016	-.023	-.002	-.069	.035	-.012	-.028	.010	-.034	-.068	-.057	.008	-.007	.003	.020	.036
DB3	.281	.083	-.017	-.046	.011	-.015	-.011	-.020	-.028	.016	.037	-.055	.005	.065	.007	.022	.000	.001	-.001	.005	-.019	-.042	.019	.011	-.006	-.066	.003	.008	-.003	-.031	.004	-.010	-.040
DB4	.142	-.070	.011	.028	.059	-.012	.015	-.074	.009	-.018	-.020	.010	.047	-.065	-.001	-.028	.025	.010	.024	-.092	.100	.039	-.011	-.017	.011	.032	.048	-.086	.033	.037	.042	.047	.046
DB5	.118	-.029	-.034	.024	.023	-.023	-.057	.006	.016	-.010	.030	-.044	.007	-.042	-.113	-.056	-.035	.025	-.045	-.059	.090	-.048	.006	.051	.001	.061	-.016	.090	.004	.047	.013	-.030	-.014
DB6	-.013	.037	.000	.005	.004	-.014	.002	-.007	-.010	.024	.011	.011	.001	.002	-.342	-.007	-.005	.018	.006	.034	-.003	-.024	-.006	-.012	-.014	-.011	.033	-.009	.014	.022	.035	-.010	-.024
DB7	.016	-.191	.049	-.017	-.051	-.032	.001	.038	-.055	-.088	.060	-.024	.024	-.021	-.008	.005	.086	.035	-.024	-.002	-.063	.042	-.009	-.009	-.011	-.007	-.008	.032	-.001	.008	.002	.031	.008
EA1	.058	-.037	-.004	.043	.018	.067	-.073	.026	.028	-.022	.066	.060	.067	-.052	-.022	.063	-.006	.069	.093	-.029	-.082	-.006	-.071	.038	.026	-.028	-.028	.102	-.036	-.028	.059	.044	.012
EA2	-.018	.075	.030	.065	.028	.015	.011	.054	.062	-.056	.008	-.034	.019	-.067	-.017	.028	.017	.036	.063	.009	.038	.001	-.050	-.007	.054	-.006	-.053	-.015	-.060	-.049	.204	.024	-.039
EA3	.071	-.077	.066	.050	.033	-.050	-.048	.040	.049	.089	-.039	.035	.050	-.045	-.012	.032	.039	.057	.072	.022	-.077	.015	-.002	-.045	.048	.003	.047	-.015	-.098	-.014	-.046	-.048	.011
EA4	-.002	-.018	.021	-.015	-.013	.019	-.022	-.008	.035	.006	-.015	-.038	-.043	-.065	.011	-.025	.321	.002	-.028	.004	.002	-.001	-.054	.018	-.041	-.036	.006	-.024	.025	.015	-.008	-.005	-.029
EA5	-.092	-.026	-.112	-.017	-.025	.044	-.056	.059	-.196	-.006	-.102	-.004	-.040	.087	-.060	-.008	.038	.038	-.028	.012	-.063	.037	-.081	.001	.077	.038	-.012	.009	-.024	.055	.010	.122	.090
EA6	-.059	.032	.092	.002	.023	-.059	.037	.107	.009	.024	.051	.015	.065	-.013	-.035	-.010	.057	-.066	.061	-.033	.039	-.067	-.009	-.022	.056	-.002	-.010	-.034	-.061	.006	.163	-.004	-.019
EA7	.025	.044	-.035	.007	-.025	-.031	.003	.095	-.044	-.024	.044	.044	.024	.024	-.020	.008	.164	-.012	.010	.025	.007	.104	.104	-.005	.176	.041	.002	-.039	.102	-.011	.051	.009	-.032
EB1	-.059	-.003	-.041	.050	.002	-.052	-.019	-.017	.017	.043	.076	.039	.044	.104	-.062	.162	.071	-.052	-.002	.041	.063	-.045	-.006	.004	.019	-.075	-.072	-.045	.023	-.039	.048	-.020	.021
EB2	-.027	.059	-.006	.007	.054	-.055	-.011	-.039	-.091	-.010	-.027	.041	-.073	.017	-.044	.051	.146	.011	.033	-.018	-.002	-.033	.059	-.095	-.005	.036	.036	-.022	-.064	-.063	-.020	-.045	.012
EB3	-.020	.042	-.029	-.018	.074	.012	.025	-.036	.021	.064	-.004	.001	-.017	.124	-.028	.010	.153	-.085	-.039	-.049	.029	.030	-.025	.071	.013	-.086	-.036	.065	-.070	.022	-.075	-.067	-.004
EB4	.022	.056	.032	.059	.130	.025	-.001	-.069	.034	.063	-.059	-.104	.045	.028	.012	-.061	-.010	.015	-.072	.052	.059	-.022	.026	.059	.260	-.025	.007	.023	-.019	-.032	.002	-.028	.061

Table K-B: Rotated Compenent Matrix

Code	Component																																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
EC1	.045	-.032	-.036	-.012	-.018	-.003	-.037	-.002	-.058	.001	.001	-.121	.007	.079	.004	.048	.000	.069	.031	.016	.042	-.073	.035	-.057	.099	.019	.048	-.072	-.011	.008	-.034	-.060	.002
EC2	.037	-.055	-.010	.004	.034	.030	-.043	.099	-.025	.059	-.130	-.092	-.038	.001	-.003	.072	-.038	-.049	.051	-.052	.126	-.005	.027	-.006	-.046	.026	.075	.053	.005	.034	-.019	-.067	-.052
FA1	-.078	.024	.043	.025	.014	.029	-.008	-.052	-.009	.004	-.057	-.035	.037	.041	-.146	.055	.001	-.021	.020	-.088	-.066	-.006	.078	.147	-.022	.094	-.104	-.018	.023	-.043	-.037	.051	-.062
FA2	.020	-.056	-.076	.077	.073	.035	.045	.050	.039	.038	-.008	.054	.059	.068	-.078	.018	-.006	-.012	.018	-.017	-.059	.131	.053	.239	-.007	-.100	-.011	.025	-.054	.029	.024	.027	-.009
FA3	.000	-.027	-.072	.053	-.046	.071	.154	.005	.116	-.004	-.118	.006	.012	.013	-.099	-.049	-.042	-.077	.030	.032	.011	-.018	.012	-.014	-.031	-.082	.076	-.043	-.011	-.017	.018	.064	-.105
FA4	.029	-.110	-.046	.032	.016	.123	-.020	-.009	.023	-.027	-.003	-.021	.018	-.024	-.063	-.019	-.052	-.009	.026	-.023	.120	.050	-.042	.052	-.005	.001	-.067	-.081	.053	.083	-.037	-.002	-.080
FA5	.039	-.017	-.024	-.020	-.068	.059	.027	-.010	-.051	-.109	.078	-.092	.028	-.047	.047	.194	.013	.011	.027	-.088	.045	-.013	-.023	-.024	-.058	.055	.023	.002	-.046	-.013	-.127	.008	-.013
FA6	-.034	.006	.035	-.042	-.025	.016	.002	-.039	-.004	.047	.016	.004	.009	.011	-.045	.035	-.061	.034	.263	-.009	-.017	.040	.002	.034	-.023	-.024	-.006	-.056	.029	.045	-.004	-.026	-.010
FA7	.009	.021	-.039	.030	.010	.017	.000	-.006	-.025	-.009	-.015	-.030	-.032	.040	.038	-.035	.024	-.015	.253	.029	-.053	.033	.017	-.032	-.027	.019	-.029	.036	.074	-.078	-.013	.000	.058
FA8	.000	-.078	.033	-.057	-.102	-.021	.015	-.043	.025	-.030	.003	-.007	.021	.046	-.014	-.055	.020	-.074	.142	-.023	.009	.043	-.043	.100	-.003	.030	.049	.085	.019	-.008	-.036	.001	-.016
FA9	-.007	-.052	-.056	-.103	-.004	.031	-.067	-.039	.025	.081	.013	-.025	-.011	.021	.060	.024	-.010	-.065	.012	.030	-.051	-.064	.009	.057	.084	.088	.096	.012	-.026	.087	.007	.051	-.037
FB1	.056	-.047	-.054	.042	.067	-.005	.051	-.198	.035	-.030	.047	-.004	-.009	-.017	-.009	.004	.010	.052	.040	.047	.046	.120	.064	-.042	.019	.043	.076	.114	.007	-.030	-.069	.004	.021
FB2	-.076	-.011	.008	.019	.072	.014	.200	-.061	.020	-.024	.021	-.023	.030	.022	.001	-.032	.024	-.038	.013	.029	.017	.057	.014	-.065	-.016	-.011	-.026	-.014	-.054	-.006	.018	.035	-.036
FB3	-.040	-.011	.034	-.006	.049	-.022	.183	.003	-.119	.048	.020	-.054	-.036	-.027	.067	.018	.065	-.005	.041	-.008	-.014	-.032	.022	-.053	-.001	-.034	.078	.037	-.009	.039	-.001	.055	.015
FC1	.008	-.004	.057	.021	.077	-.001	.066	-.073	.045	.050	.096	-.001	.083	.008	-.010	.100	.039	.016	-.072	-.054	-.073	-.039	-.039	.043	.006	.055	-.035	.002	.020	.067	-.015	.049	.031
FC2	.040	-.016	.051	-.007	.161	.038	.012	-.049	.044	.040	.070	-.018	.068	.029	.073	.009	.049	-.041	-.052	-.045	-.072	-.085	-.038	.013	-.017	.038	-.048	.016	-.027	.019	.024	.054	.008
FC3	.071	-.010	-.035	-.043	.053	-.014	-.020	-.016	.040	.090	.005	-.028	.036	-.017	-.046	-.060	.040	-.101	-.052	-.008	.000	-.058	.021	.001	.003	.119	-.022	-.005	-.081	.025	-.025	.039	-.036
FC4	.006	.012	-.006	-.029	-.054	-.038	-.014	-.018	.002	-.035	.018	.004	-.028	-.006	-.019	.001	.038	-.014	-.054	-.024	-.044	.064	-.010	-.017	-.002	-.018	-.016	-.026	.017	-.008	-.010	.292	.008
FC5	-.024	.045	-.002	-.018	.042	-.001	-.020	.047	-.033	-.008	.009	-.015	-.004	-.038	-.023	.006	-.059	.084	.008	.026	.030	.011	.051	.009	-.070	-.061	-.069	.018	.023	-.009	-.038	.217	-.083
FC6	.023	-.015	-.034	.029	-.019	-.058	.028	-.003	-.036	.080	-.009	.045	-.021	-.005	.077	-.043	-.051	-.035	.036	.034	.081	.014	.017	-.066	.062	.059	.010	.017	.022	-.024	-.019	.165	-.010

Table K-C: Rotated Compenent Matrix

Appendix L – UCPBD Assessment Tool Sheet

Office Name	
Architect Name	
Project Location	

Scoring
Implantation or consideration of factors in Design

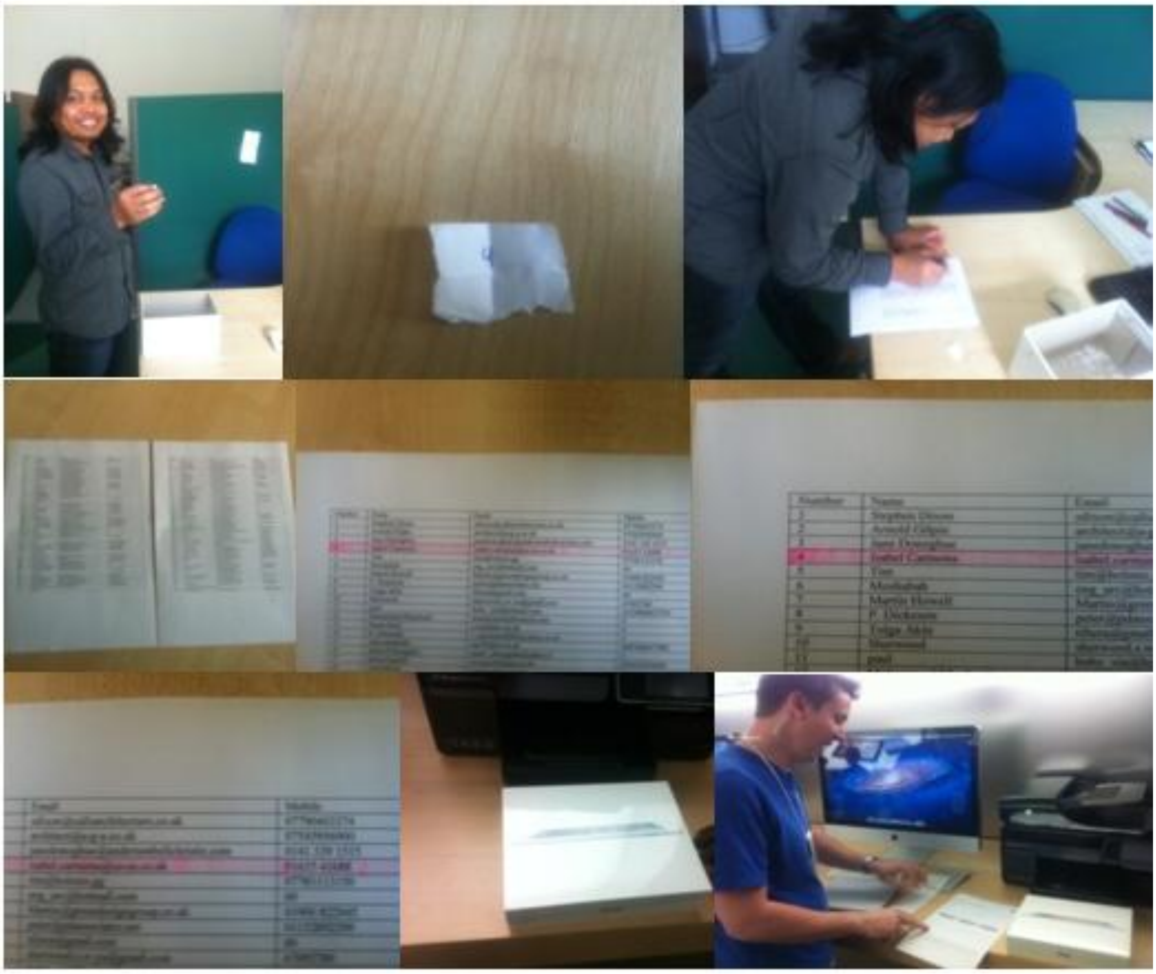
0 ← 5 → 10
Not implemented ← Considered → Highly Implemented

Case study :

	To what extents the following factors are implemented and considered in this design?	F.S	T.P	D.P	W_s	Mean	W_{ms}
Passive Design Function-ality (PDF)	**AA3:** Use nearby landforms and structures for wind protection and summer shading						
	AB2: Use low mass construction to allow rapid heat-up or cooling of structure						
	AB3: Shape the building to maximise exposure to [winter sun and summer breezes]						
	AB4: Use high mass construction with appropriate insulation to promote night ventilation						
	AC1: Subdivide interior to create separate heating and cooling zones						
	AC2: Locate thermal mass on the floor and wall to be exposed to direct sunlight if possible						
	AC8: Consider interior surface colours and finishes for optimum day lighting						
	AC9: Design plan to create buffer zones from the summer radiation						
	AC10: Plan specific spaces or functions to coincide with solar orientation						
	AC11: Narrow floor width to optimise natural ventilation						
	AD2: Use skylight, light tube and clerestory for natural illumination						
	AE4: Use Trombe wall or double façade to collect solar gain						
	AE6: Minimise openings in envelope to reduce thermal gain						
	AE8: Develop details to minimise air infiltration and ex-filtration						
	AE10: Use louvred wall for maximum ventilation control						
Passive Design Perfor-mance (PDP)	**BB2:** Select good colour to use						
	BB6: Space layout enhances or interferes with well-being of occupants						
	BC1: The temperature controls provide for the needs of different occupants						
	BC2: Thermal comfort in spaces enhances or interferes with well-being of occupants						
	BD1: A comfortable internal air temperature						
	BE3: The visual comfort of the lighting (e.g., glare, reflections, contrast)						
	BE4: The lighting quality enhances or interferes with well-being of occupants						
	BE5: Atrium or rotunda control devices for optimum space comfort						
Passive Design Usability (PDU)	**CA1:** Optimum position of service and passive element or equipment for operability						
	CA2: Consider the dimensions of passive spaces to suit human scale (avoiding undersize or oversize areas)						
	CA3: Group homogeneous passive functions together for efficient operability						
	CA4: Avoid slopes and steps of passive space floors						
Passive design Flexibility (PDFL)	**DA3:** Allow ample floor-to-floor height for future modification						
	DA9: Design passive space to respond to changes in climate conditions						
	DB2: Design passive building to adapt for dysfunctional future utilisation						
	DB3: Flexible access within and between passive spaces						
	DB4: Consider the passive design that accommodates fundamental changes in user prefer-ences						
	DB5: Design the passive space to cope with changes in flow of users						
Passive design Reliability (PDR)	**EA2:** Provide optimum drainage and venting to minimise accumulation of moisture						
	EA4: Select components that are resistant to environmental agents						
	EB4: Use standardisation of passive design elements and materials						
Passive Design Maintaina-bility (PDM)	**FA2:** Simplify interface of passive design elements and building facade						
	FA6: Design for ease to remove or replace lighting, ventilation and thermal comfort elements						
	FA7: Design for ease to adjust lighting, ventilation and thermal comfort physical element features						
	FC3: Access routes of passive space for transport of maintenance materials						
	FC4: Critical lighting, ventilation and thermal comfort element should be visible for inspec-tion						
	FC5: All elements of the external passive building shell should be easy to access for mainte-nance and cleaning						
	FC6: Optimise sizes for passive design openings for workmanship access						
	FC7: Locate passive design elements where they are accessible for maintenance and repair						

Result without weight	UCPBD tool = $\sum \frac{\text{PDF+ PDP+ PDU + PDFL + PDR+ PDM}}{440} * 100$	UCPBD tool =
	The Result =	UCPBD Rate =
Result with weight	C.Mean= $\frac{Meqan\ Equation}{\sum W_s\ of\ each\ culster*10} * 100$	C.Mean =
	The Result =	UCPBD Rate =

Appendix M – Draw Prize Process



Apple Retail Domestic Shipping Form

Customer Shipping Information

Isabel Carmona

Suite 6, Newbury Town Hall

Market Place, Newbury RG14 5AA

01635 41658

isabel.carmona@ca-aa.co.uk

Shipping Information

718908460979

718908461297

718908412909

1

40497581 9

Comments

Leave at reception if nobody in.

I understand and accept the following

Ali AlZAED

07/07/2012

From: General1 [ca-sa@ca-sa.co.uk]
Sent: 11 July 2012 14:00
To: Alzaed, Ali
Subject: RE: Congratulation

Dear Ali,
As mentioned this morning the parcel with the iPad had arrived. Thanks very much indeed.
All best
Isabel Carmona

From: Alzaed, Ali [mailto:A.Alzaed@liverpool.ac.uk]
Sent: 07 July 2012 22:13
To: General1
Subject: Congratulation
Dear Isabel
I hope all is well with you.
I paid the cost of the IPad and they told me that they will deliver it to you this monday. Please let me know when you recieve it. By the way, I put the note which you asked me in your email.
I lookforward to hearing from you .
Regards
Ali Alzaed
PhD Candidate
School of Architecture
University of Liverpool

From: General1 [ca-sa@ca-sa.co.uk]
Sent: 29 June 2012 15:32
To: Alzaed, Ali
Subject: RE: Congratulation

Dear Ali,
Thanks very much, hope the input into the questionnaire was also helpful and that your research is going well.
My details are as shown below:
Isabel Carmona
ca sustainable architecture
Address:
Suite 6, Newbury Town Hall,
Market Place, Newbury RG14 5AA
Tel: 01635 41688
Please add a note when you send it to leave it at reception if I am not in (about to go away for 10 days).
All best,
Isabel Carmona

From: Alzaed, Ali [mailto:A.Alzaed@liverpool.ac.uk]
Sent: 29 June 2012 13:25
To: isabel.carmona@ca-sa.co.uk
Subject: Congratulation
Dear Ms Carmona,
I hope this email finds you well.
It is my pleasure to inform you that after completing the user centered passive building design survey online your name was drawn and won an Apple iPad2 16GB. Congratulation.
Please send me your full name, contact details and address to be able to send you the item.
Thanks for your particpation.
Regards,
Ali Alzaed
PhD Candidate
School of Architecture
University of Liverpool

Appendix N – List of Puplications

- Alzaed, A and Boussabaine, A., H, (2012), Passive Building Design: a User Centered Approach , Proceedings of the 1st International Conference on Building Sustainability Assessment, Porto, Portugal, ISBN: 978-989-95671-6-0.

- Alzaed, A and Boussabaine, A., H, (2012), User Centred Passive Building Design: Attributes and Sub-Attributes , Proceedings of the *9th European Conference* of Product and Process *Modelling* , Reykjavik, Iceland, ISBN-13: 978-0-415-62128-1.

- Alzaed, A and Boussabaine, A., H, (2012), Integration User Needs into Passive Building Design , Proceedings of Zaytoonah University International Engineering Conference on Design and Innovation in Infrastructure 2012 (ZEC Infrastructure 2012), Amman, Jordan.

- Alzaed, A and Boussabaine, A., H, (2012), User Centred Passive Building Design: Who is the End User?, Proceedings of Zero Energy Mass Customs Homes (ZEMCH 2012), Glasgow, UK.

- Alzaed, A and Boussabaine, A., H, (2012), A Conceptual Model for User-Centered Passive Building Design, Proceedings of the 26th Annual Conference (Association of Researchers in Construction Management (ARCOM), Edinburgh, UK, ISBN: 978-0-9552390-6-9 (2 Vols.).

- Alzaed, A and Boussabaine, A., H, (2012), Towards a New Methodology for Integrating User Aspirations into Passive Building Design , Proceedings of the 3rd EPPM (Engineering, Project and Production Management) International Conference, Brighton, UK.